

2021 STATE OF THE INDUSTRY REPORT

Cultivated meat and seafood



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The Good Food Institute (GFI) is an international network of organizations developing the roadmap for a sustainable, secure, and just protein supply. We identify the most effective solutions, mobilize resources and talent, and empower partners across the food system to make alternative proteins accessible, affordable, and delicious.

This report, as well as all of GFI's research, data, and insights, is made possible by gifts and grants from our global family of donors.

GFI's **State of the Industry Report** series dives deep into the key technologies, business developments, and scientific advances driving the alternative protein industry forward:

- Cultivated meat and seafood
- Fermentation: Meat, seafood, eggs, and dairy
- Plant-based meat, seafood, eggs, and dairy
- Industry update: Alternative seafood

The Good Food Institute is not a licensed investment or financial advisor, and nothing in the state of the industry report is intended or should be construed as investment advice.

Introduction

Every year, we see new advancements in the alternative protein industry that are opening the door for a global shift to a far more sustainable, secure, and just food system. Like 2019 and 2020 before it, 2021 was the most active year yet for growth in the alternative protein industry, and many signs indicate that the world is on the cusp of a global race for alternative protein innovation.

By making meat from plants, through fermentation, or through cultivation of actual animal cells, we can reduce the harmful climate impacts of our food system, decrease the risk of zoonotic disease and antibiotic resistance, and feed more people with fewer resources. We can also slow biodiversity loss, reduce air and water pollution, and preserve our oceans. Indeed, alternative proteins are to meat production as renewables are to energy: the future. As the global community strives to mitigate climate risks, alternative proteins stand as an enormous opportunity that can help us reach net-zero emissions—but more investment and open-access R&D are needed.

Alternative proteins offer some of the most game-changing research opportunities with potential for global societal impact—stabilizing the climate and preserving biodiversity while eliminating food’s contribution to pandemic risk and antibiotic resistance. But to date, alternative proteins have not been appropriately prioritized. Investment in this nascent field is pennies on the dollar compared with investment in electric vehicles and renewable energy, yet livestock’s global greenhouse gas emissions are on a par with those from transportation (see [gfi.org/climate](https://www.gfi.org/climate)). Together, increased public and private investments in alternative proteins can write the next technological chapter for agriculture and spur economic growth while improving both environmental and global health outcomes.

Cultivated meat and seafood are a critical piece of the puzzle. The promise of cultivated meat is its indistinguishability from conventional meat—from each bite all the way down to the cellular level. And since the technology behind it offers a means of meat production that can be decarbonized, cultivated meat provides a compelling way to heed the climate community’s call to “electrify everything.”

As the industry scales up, we’re seeing the first pilot production facilities open and governments beginning to clear a path to market for cultivated products. In fact, China included cultivated meat in its newly released five-year agricultural plan. These steps pave the way for cultivated meat to come to market in more places, at greater scale, with lower costs, and with the support of global decision-makers. As the sector advances toward commercialization, it is emerging as a deployable food technology that can help us feed a growing population and enable a more stable, secure global food system.

As with all new technologies, many critical open questions remain. Ongoing and future research must address key technical challenges in the industry, which is why support for research from both public and private sectors is crucial. Given what is at stake, we must invest significant resources to ensure that cultivated meat has the greatest chance of success.

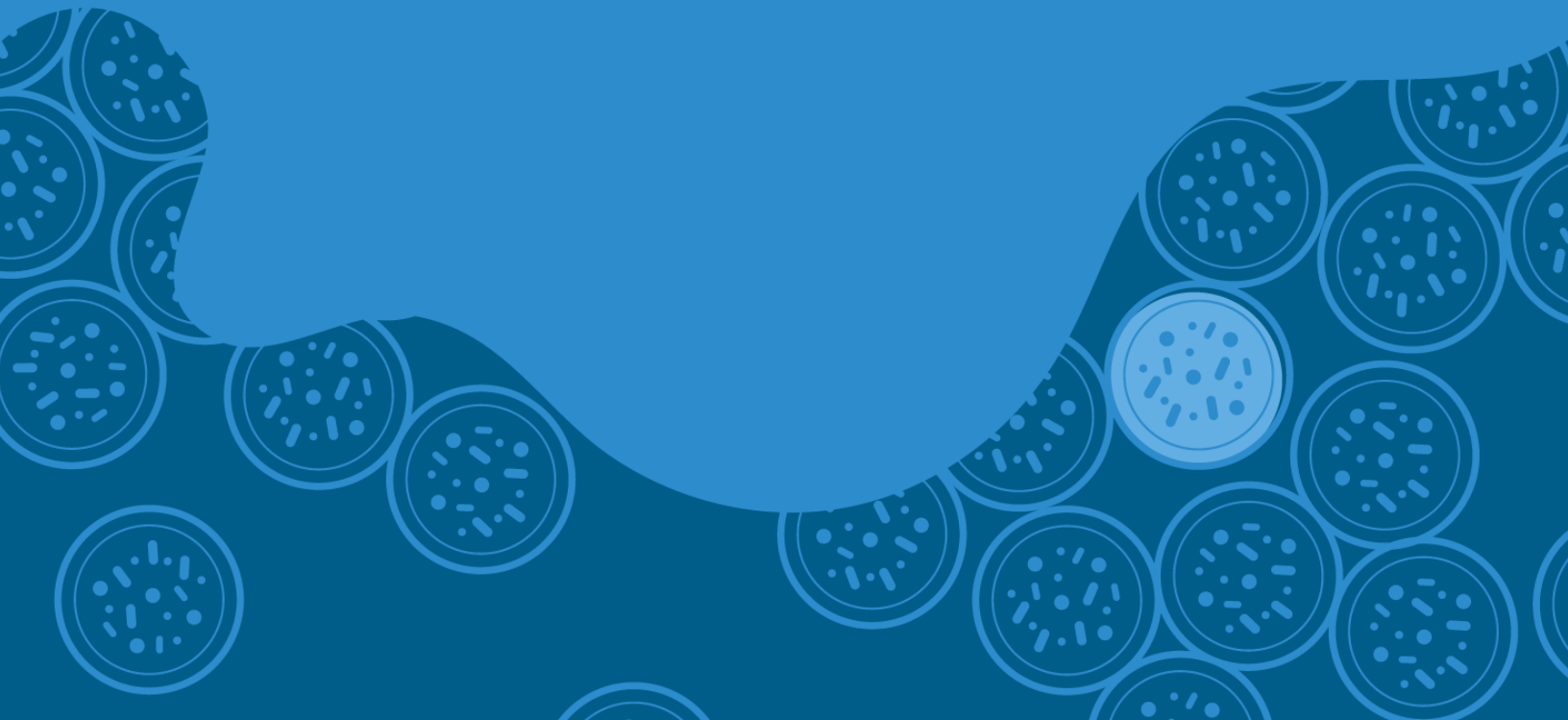
We present this State of the Industry Report, Cultivated meat and seafood, to highlight the sector’s key developments in 2021 and look ahead to what’s next.



Caroline Bushnell

VP of Corporate Engagement at the Good Food Institute

Executive summary



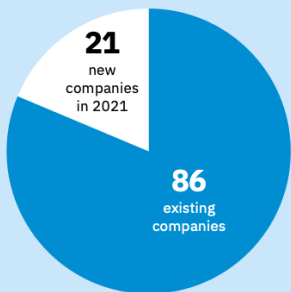
Executive summary

2021 was a year of robust activity and progress in the cultivated meat industry. Governments invested new public funding, the United States launched a center for excellence in cellular agriculture at Tufts University, and more countries made strides in the race to approve cultivated meat products.

The supply chain strengthened as several new pilot-scale production facilities opened, and the largest meat company in the world signaled its confidence in the industry with a \$100 million investment and an announcement that it would go to market with cultivated meat by 2024. The world’s first-ever life-cycle assessment and techno-economic analysis for cultivated meat that involved industry and government data and participation were published, creating the most inclusive picture ever of what a global transition to cultivated meat might look like. These studies also spurred healthy conversation about the future of cultivated meat, illustrating the need for further research and development in the sector.

Commercial landscape

Companies dedicated to producing cultivated meat



↑ 24% YOY increase

Facility launches. Several landmark facilities opened in 2021, including Future Meat’s pilot plant, Wildtype’s pilot plant with annual production capacity of 200,000 pounds, UPSIDE Foods’ facility with current production capacity of 50,000 pounds and future capacity of 400,000 pounds, and Shiok Meats’ mini plant for cultivated seafood R&D.

Geographic expansion. 2021 saw the first launches of cultivated meat companies in Mexico and Brazil and a cultivated seafood company in Africa.

Activity from the world’s largest meat company.

JBS, the largest protein company and the second-largest food company globally, announced a \$100 million investment that includes the following:

- 1) An agreement to acquire Spanish company BioTech Foods and invest in the construction of a new production facility in Spain.
- 2) Establishing Brazil’s first cultivated protein R&D center.

Figure 1: 2021 cultivated meat around the globe

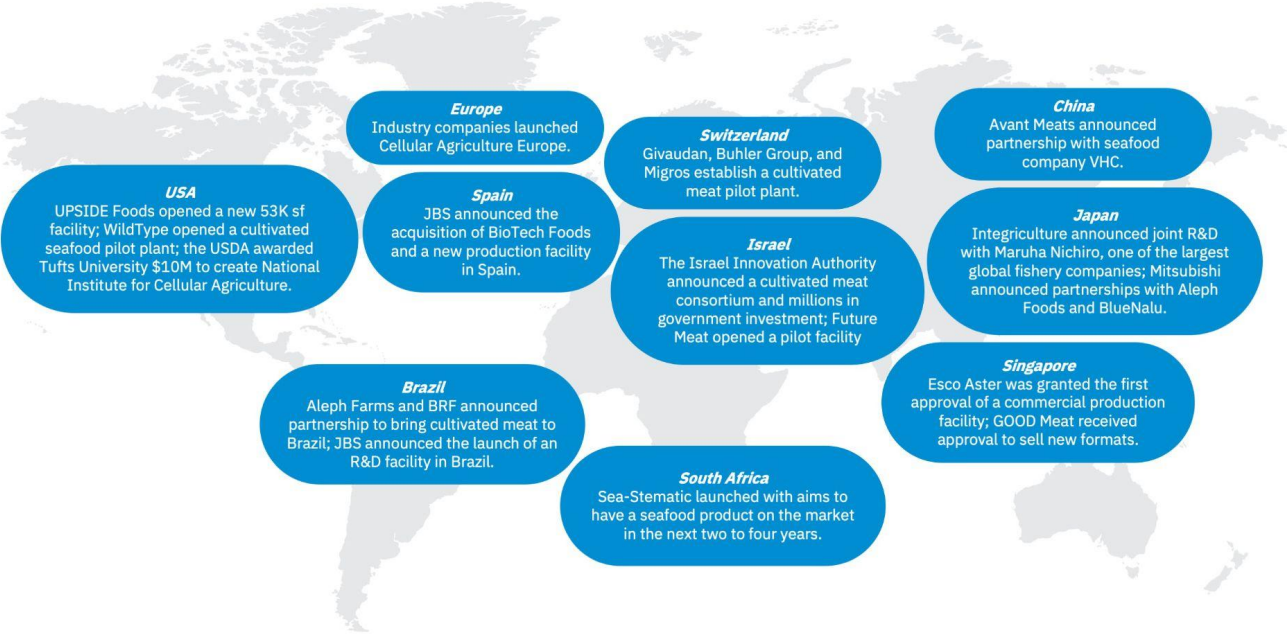
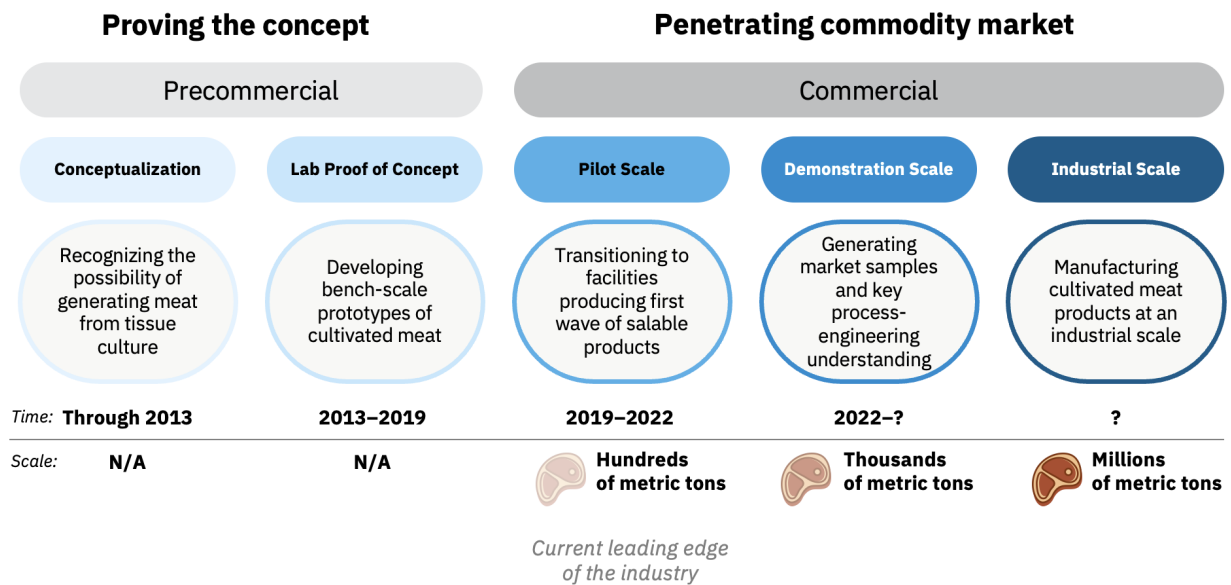


Figure 2: Leading edge of cultivated meat production



Companies at the leading edge of the industry are now manufacturing cultivated meat at pilot scale, a crucial early step to assess the viability of industrial-scale production.

Investments

Investment in cultivated meat companies topped \$1.36 billion in 2021, more than doubling the previous cumulative investment in the industry. 2021 also saw more than a hundred new investors enter the space.

Category	2021	2020	All-time (since 2016)	2021 highlights
Total invested capital	\$1.38B	\$410M	\$1.93B	2021 invested capital grew 336% from 2020.
Invested capital deal count	64	51	188	2021's largest investment was \$347M (Future Meat Tech.).
Unique investors	258	157	453	The number of new unique investors grew by 62% in 2021.
Growth stage deals (Series B and above)	8	1	9	These included Eat Just, Future Meat, Finless Foods, and Mzansi Meat.
Liquidity events	\$18.6M	\$0	\$18.6M	MeaTech acquired cultivated fat producer Peace of Meat.

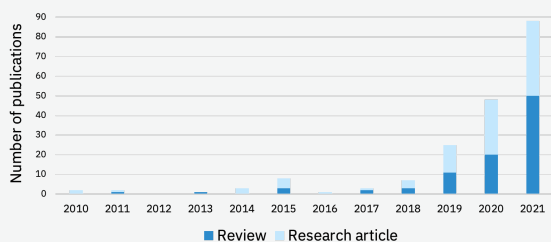
Science and technology

In 2021, the science and technology landscape for cultivated meat accelerated:

Techno-economics. In late 2020 and early 2021, three techno-economic analyses of hypothetical commercial-scale cultivated meat production were published: [Humbird, 2020](#), and [2021](#); [Vergeer, 2021](#) (funded by GFI and using industry-provided data); and [Risner, 2021](#).

Open-access R&D. [Companies](#) and [academic laboratories](#) continue to push the boundaries of cultivated meat research. In 2021, GFI awarded [research grants](#) for 22 innovative projects related to cultivated meat.

Scientific papers. Research into cultivated meat is heating up. GFI's science and technology team has been tracking scientific publications focused on cultivated meat, and each year the numbers continue to rise.



Government and regulation

As of the end of 2021, Singapore remains the only nation to approve the sale of a cultivated meat product. But other countries are making strides in the race to approve and invest in these products:

Momentum in Israel. In preparation for his first meeting with U.S. president Joe Biden, Israeli prime minister Naftali Bennett was briefed by GFI Israel on the importance of alternative proteins to climate change mitigation. GFI Israel's managing director also served on the country's official delegation to COP26.

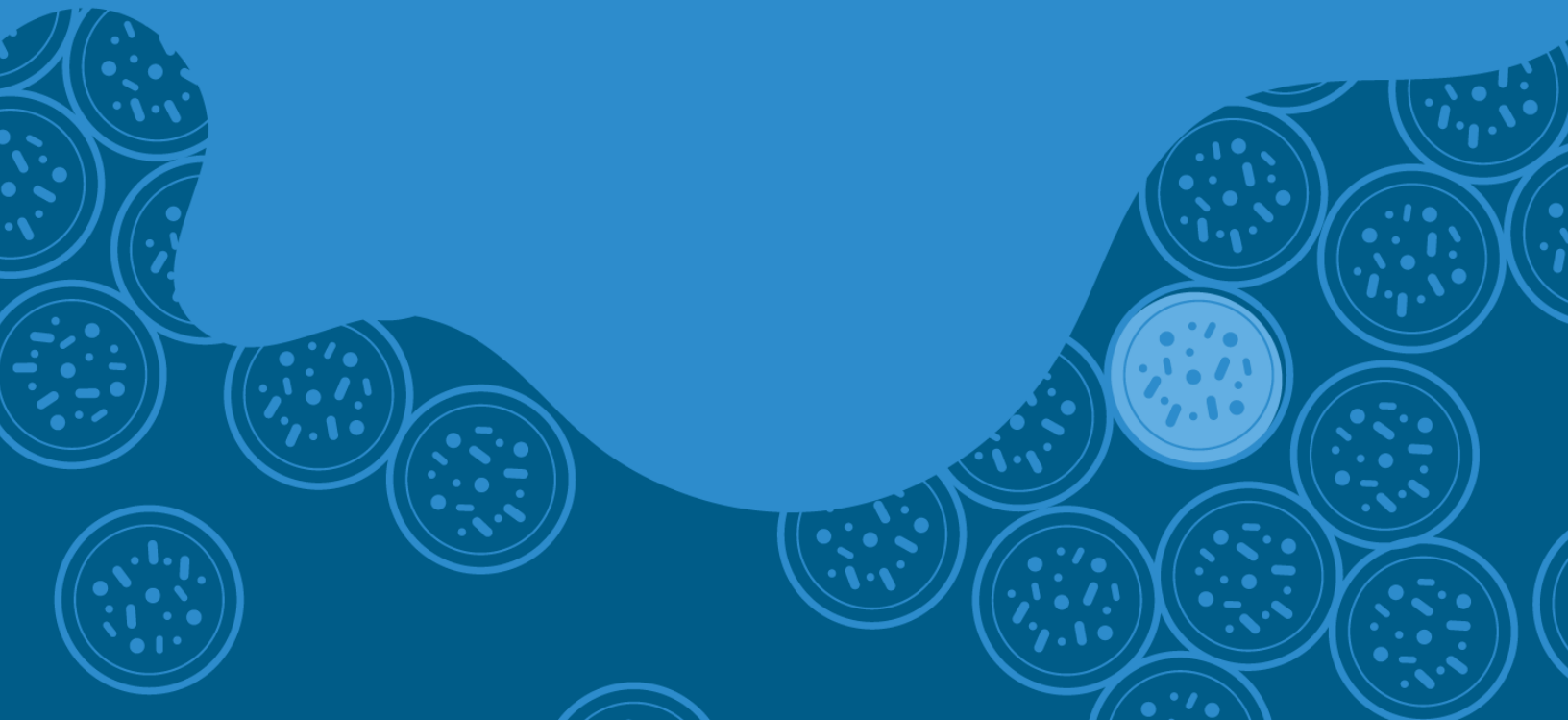
Public funding. The Israel Innovation Authority announced a ₪220 million (\$69 million USD) investment in four new innovative consortia, including a cultivated meat consortium composed of companies and research institutions.

In October 2021, the EU government funding program REACT-EU, launched in response to the Covid-19 pandemic, awarded cultivated meat company Mosa Meat and partner Nutreco a €2 million grant for research into lowering the cost of cell culture media.

The USDA announced an award of \$10 million for the creation of a [center of excellence](#) in cellular agriculture at Tufts University, and the U.S. National Institutes of Health granted [\\$1.5 million](#) to Defined Bioscience to develop a cell culture medium supplement.

Section 1

Commercial landscape



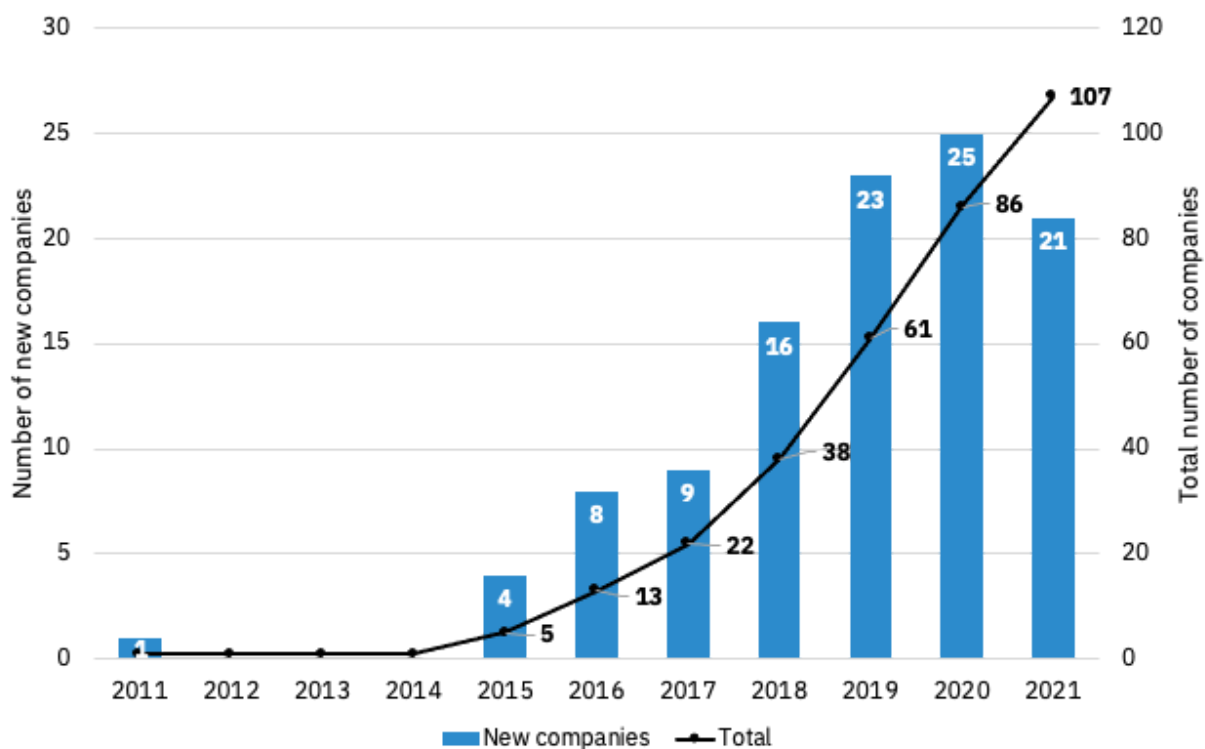
Section 1: Commercial landscape

Overview

Entrepreneurial activity in cultivated meat continued at a rapid pace in 2021:

- At least 21 new cultivated meat ventures emerged.
- The number of startups focused exclusively on developing cultivated meat inputs or end products rose to 107.
- The number of companies, largely in the life sciences, that have publicly announced a business line in cultivated meat increased to 64.

Figure 3: New and total number of cultivated meat companies, by year founded



Sources: GFI company database, PitchBook, Crunchbase, manufacturer websites.

Major developments

Cultivated meat activity was not immune to the widespread disruptions in global supply chains brought about by Covid-19. Delivery of bioreactors and other critical inputs faced delays due to increased demand for vaccine production from the pharmaceutical sector, as well as other upstream shortages. Nevertheless, the cultivated meat category made enormous progress in 2021, hitting key milestones and moving a step closer to its full potential of reimagining our global food system.



“The cultivated meat industry is at an inflection point as more and more companies shift their focus from R&D to scale-up. As companies start to scale, volume and unit economics will become critical. The conversation is already starting to shift from can we make something to how much can we make and for how cheap.”

—Yossi Quint, founder and CEO, Ark Biotech

Commercial launch announcements

Almost a year after Eat Just’s historic **December 2020 launch of cultivated chicken bites in Singapore’s 1880 restaurant**, the **Singapore Food Agency granted regulatory approval to Eat Just’s GOOD Meat division** to launch cultivated chicken breast. In 2021, multiple companies made strides toward commercial launch, pending regulatory approval:

- January 20: **BlueNalu raised \$60 million, gearing up for commercial launch of cultivated seafood**. BlueNalu also secured partnerships with Nomad, Mitsubishi, and Thai Union later in the year.
- June 10: **California’s Finless Foods announced the launch of “sushi grade” cultivated tuna** with aims to distribute in foodservice by 2022.
- June 23: Future Meat Technologies indicated it was **gearing up for a U.S. launch in 2022**, pending regulatory approval.
- July 20: UK-based **Ivy Farm Technologies** announced plans to open an on-site restaurant by 2022, with a retail launch in 2023.
- August 25: Australian cultivated meat startup Vow and precision fermentation startup Nourish Ingredients **formed a partnership** to develop cultivated meat with fermentation-derived fat, and they plan to launch the first products in Singapore.
- August 31: **UPSIDE Foods partnered with three-Michelin-star chef Dominique Crenn to serve cultivated chicken** in her restaurant, Atelier Crenn. Crenn also provides culinary counsel and recipe development to UPSIDE.
- September 30: Cultivated fat startup Mission Barns and sausage maker Silva Sausage **hosted tasting events and conducted a pilot production run** for their hybrid sausages made with cultivated fat and plant proteins, with plans to launch in the United States. Mission Barns also **partnered** with HEROTEIN for plant-based meat with cultivated fat, to be launched in mainland China.

- October 4: **New Age Meats declared plans to launch a hybrid cultivated and plant-based sausage in 2022 after completing a successful \$25 million Series A.**
- December 13: Wildtype announced distribution **agreements** with a poké restaurant chain and a retail sushi bar operator.

Hybrids on the horizon

As costs decrease and production volumes go up, cultivated meat companies are increasingly poised to begin commercial launches as soon as they obtain regulatory approval. While regulatory pathways to market are the current bottleneck, any near-term commercial launches would still be very small scale, with limited product availability and premium positioning owing to the high cost of producing smaller volumes. Hybrid products—cultivated meat and fat supplemented with plant-based or fermentation-derived proteins—offer potential to accelerate launches and make cultivated meat ingredients accessible to a wider group of eaters while improving the organoleptic properties of alternative protein products.



The world's first cultivated meat billboard was erected in Singapore.

Image credit: Eat Just, Inc. / GOOD Meat

Firsts

2021 saw cultivated meat hit several new first-time business and technical milestones, including debuting new format prototypes, business-to-business inputs, and product categories:

- January 7: Mexico saw its first cultivated meat startup, **Micro Meat**, which participated in the summer 2021 batch of Y Combinator.
- January 27: **Spanish food tech startup Novameat 3D-printed the “world’s biggest” cultivated meat prototype.**
- February 10: **Aleph Farms and Technion debuted the world’s first cultivated ribeye steak prototype.**

- April 20: **Cultivated meat became available for home delivery in Singapore.** Eat Just partnered with popular food-delivery app Foodpanda to deliver cultivated chicken straight to consumers.
- April 22: The world's first **cultivated meat billboard** was put up in Singapore.
- May 28: **Africa's first cultivated seafood company**, South Africa-based Sea-Stematic, launched with aims to have a seafood product on the market in the next two to four years.
- July 27: **Higher Steaks announced the world's first cultivated pork belly.**
- September 15: Singapore-based Esco Aster obtained the **world's first regulatory approval of a cultivated meat manufacturing platform**, becoming the first manufacturing platform to obtain regulatory approval to develop and produce cultivated meat at commercial scale as a contract development and manufacturing organization, a development that could accelerate the path to market for cultivated meat startups.
- September 17: **Shiok Meats unveiled the world's first cultivated crab meat.** The company is now working to build Singapore's first cultivated seafood factory and aims to bring a product to market by 2023.
- September 21: **MeaTech Group produced 700 grams of cultivated chicken fat in one production run.** In December, **MeaTech also revealed it had bioprinted a 3.67-ounce steak—the largest cultured steak produced to date.**
- September 30: Chef David Chang **discussed the benefits of cultivated meat** in his Hulu docuseries, *The Next Thing You Eat*, that premiered in October.
- September: **Ambi Realfood** launched as the first Brazilian cultivated meat startup. The project raised an initial investment of R\$200,000 after winning a public notice for the Techfuturo program of the Research Support Foundation of the State of Rio Grande do Sul.
- November 21: Ivy Farm offered the world's **first cultivated hot dog tasting at COP26.**
- December 17: CellMEAT debuted the world's first **cultivated dokdo shrimp prototype** in South Korea.

Tasting events

Tasting and sampling events continued in 2021, as cultivated meat companies lowered costs and were able to produce more substantial quantities of cultivated meat than ever before:

- February 9: **Aleph Farms debuted 3D-printed ribeye** and continued operating their **visitor center** to help establish transparency and trust-building with consumers.
- March 31: **Supermeat showcased The Chicken restaurant**, their **hybrid restaurant concept and pilot plant.** The Chicken is an innovative concept that brings the consumer closer to both the production and the organoleptic experience of cultivated meat.
- May 21: Korea-based startup SeaWith debuted cultivated beef bites in a tasting event in Seoul. The company uses seaweed-based cell culture and scaffolds and aims to launch in restaurants in 2022.
- August 28: **Shiok Meats debuted the first cultivated crab at a tasting event in Singapore.**
- September 4: **Chinese startup CellX unveiled cultivated pork in a tasting event.**

- October 22: Wildtype held a cultivated salmon tasting at the Cultured Meat Symposium conference and **live-streamed during a Stanford alt-protein project event**. Wildtype will also **serve sushi** at their pilot plant.
- October 25: Israeli president Isaac Herzog became the world's first president to try cultivated meat, following in the footsteps of Israeli prime minister Benjamin Netanyahu, who in December 2020 **became the first head of state to sample cultivated meat**. GFI Israel organized both tastings.
- November 12: Ivy Farm offered the world's **first cultivated hot dog tasting at COP26**.
- November 22: Senior management of the Food and Agriculture Organization of the United Nations (FAO) in Rome tasted cultivated steak from Aleph Farms at an event hosted by the Israeli Embassy to the FAO, supported by GFI Israel.

Geographic expansion

2021 saw the first cultivated meat companies launched in Mexico and Brazil, along with the first African cultivated seafood startup. These additions, along with other new entrants and existing players, expanded cultivated meat's global footprint.

Figure 4: Distribution of companies by country

Australia	3	Germany	4	Singapore	9
Brazil	1	India	2	South Africa	3
Canada	5	Israel	14	South Korea	3
Chile	1	Italy	1	Spain	2
China	5	Japan	3	Switzerland	1
Croatia	1	Mexico	1	Turkey	1
Czech Republic	2	The Netherlands	4	United Kingdom	12
France	2	Russia	1	United States	26

1–9 companies
10–19 companies
20+ companies



“Partnerships across the value chain will play an important role in this next chapter. Whether it’s culinary partnerships—like the one we announced with three-Michelin-starred chef Dominique Crenn—or collaborations to develop the supply chain for critical components, creative and broad coalitions will be critical to realizing our industry’s vision and potential.”

—Amy Chen, COO, UPSIDE Foods

New and total cultivated meat companies by region

Region	Number of new companies	Number of total companies
Africa and Middle East	8	17
Asia Pacific	5	26
Europe	2	29
Latin America	2	3
North America	4	32
Global	21	107

For the full list of known cultivated meat companies, please see [GFI's company database](#) and [contract manufacturer directory](#).

Game-changing facilities

The scale-up of a bioprocess, whether for production of biofuels, therapeutic antibodies, or cultivated meat, generally occurs in four phases: **lab scale**, **pilot scale**, **demonstration scale**, and **commercial (industrial) scale**. Pilot scale, in particular, is an essential proof of concept that enables companies and investors to assess raw-material and production costs as well as product yield.

Pilot-scale cultivated meat facilities will produce hundreds or thousands of kilograms of biomass annually. This means that companies are likely to have capacity to supply a limited number of high-end restaurants in the coming one to three years, along with producing samples for regulators and key industrial partners.

Facilities that opened in 2021:

- June 23: **Future Meat pilot plant opened**. Israel-based Future Meat is using its **pilot plant** to develop products to market worldwide. The company hopes to launch cultivated chicken and **break ground on a new production facility** in the United States in 2022.

- June 24: **Wildtype pilot plant launched.** Wildtype's San Francisco-based pilot plant can make up to 200,000 pounds of cultivated sushi-grade salmon a year once fully operational and is designed with consumer transparency as a central focus, with a tasting room and education center on-site.
- November 4: **UPSIDE opened the EPIC pilot facility.** UPSIDE Foods opened their cultivated meat Engineering, Production, and Innovation Center (EPIC), a 53,000-square-foot facility with the capacity to produce 50,000 pounds of meat per year and a future capacity to produce more than 400,000 pounds.
- November 23: **Shiok launched a mini pilot plant.** Shiok Meats opened a mini plant for cultivated seafood R&D. The facility is a first in the region and was officially opened by Singapore's minister for sustainability, Grace Fu.

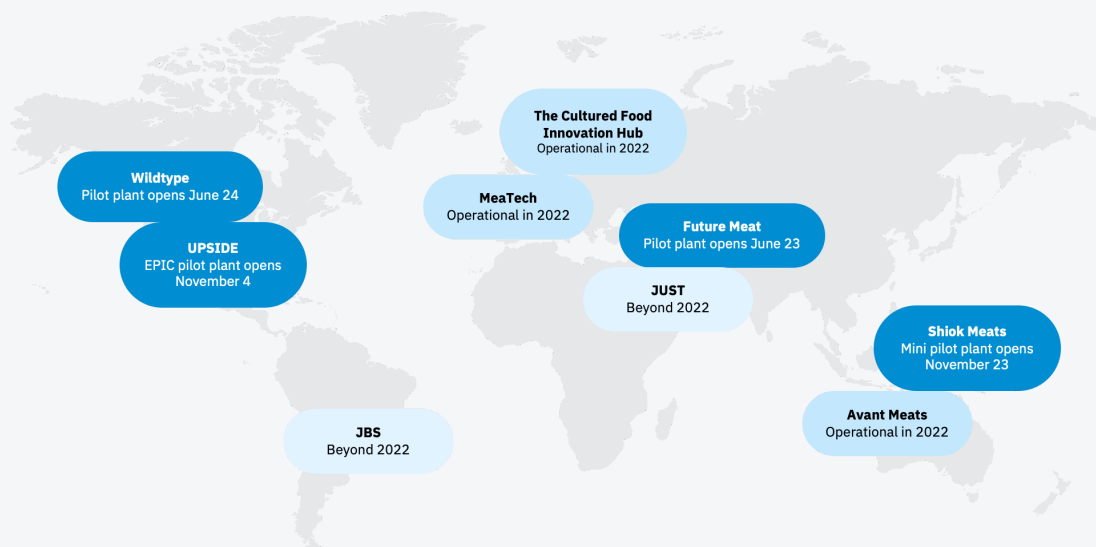
Facilities announced to be operational in 2022:

- **Avant Meats is set to open a production facility for cultivated fish cells in Singapore by 2022.** The facility will include a research laboratory in collaboration with the Agency for Science, Technology, and Research (A*STAR) Bioprocessing Technology Institute.
- **Givaudan, Buhler, and Migros plan to form a pilot plant for cultivated meat. The Cultured Food Innovation Hub** near Zurich, Switzerland, will provide production capacity, consulting, and product development services to support cultivated meat startups.
- **MeaTech plans to open a pilot plant in Europe to produce cultivated chicken fat to enhance meat alternatives.**

Facilities announced for beyond 2022:

- **JBS plans to construct a new cultivated meat plant in Europe.** The world's largest meat company is investing US\$100 million in cultivated meat via a new R&D center for cultivated protein in Brazil, the acquisition of cultivated meat startup BioTech Foods, and a pilot-scale facility in Spain.
- **JUST is planning a facility in Qatar.** Eat Just is working with the Qatar Free Zones Authority and the Ministry of Public Health to secure regulatory approval and an export license for its GOOD Meat. Eat Just also **plans to invest in U.S. and Singapore facilities.**

Figure 5: Map of current and future facilities



Infrastructure needs remain

While these facilities represent exciting advances for the cultivated meat industry, significant hurdles remain. Even as companies like **Esco Aster** and **Ark Biotech** scale production infrastructure for cultivated meat, expected needs far outstrip existing global bioreactor capacity. Annually, about **340 million tons** of meat and **200 million tons** of seafood are produced globally. **According to McKinsey's analysis**, reaching even 1 percent of this market will require 220 to 440 million liters of capacity, eclipsing the estimated 10 to 20 million liters of pharmaceutical-grade cell-culture capacity currently built.

Closing this volumetric gap will require massive investment in cultivated meat infrastructure. But promising precedents exist. Other world-saving technologies with high capital costs, such as renewable energy, have pulled off such a feat: **Clean energy investment grew seven times from 2004 to 2019, from \$40 billion to \$282 billion**, representing a 14 percent CAGR over 15 years. Notably, in the past few years, China has rapidly ramped up its offshore wind energy production to 26 GW in 2020, now accounting for **half of global offshore wind energy production**.

More information about cultivated meat infrastructure needs and financing considerations can be found in the **CE Delft techno-economic analysis**.

Cultivated meat ventures



Please visit [this link](#) for a full list of all known cultivated meat companies.

Company	Brief Description	Year Founded	Website	Logo
Aleph Farms	Aleph is working on cultivated beef steak, ...	2016	https://www.aleph-farms.com/	
Alife Foods	Startup working on cultivated meat proces...	2019	http://alifefoods.de/	
Ambi Real Food	Ambi Real Foods is Brazil's first cultivated ...	2021	https://ambirealfood.com/	
Animal Alternative Technologies	Animal Alternative Technologies is an engin...	2020	https://www.animalaltern...	
ANJY MEAT	A B2C cultivated meat company on a missi...	2021	http://anjymeat.com/	
Another Fish	Canadian company that produces cell-cult...	2021	www.another.fish	
Ants Innovate	Singaporean deep tech start-up focusing o...	2020	https://www.antsinnovate...	
Appleton Meats	Appleton Meats is a cellular agriculture co...	2017	https://www.crunchbase...	
Ark Biotech	U.S.-based company that produces scalabl...	2021	https://www.ark-biotech...	
Artemys Foods	Startup working on cultivated meat	2019	https://artemysfoods.com/	
ArtMeat	Startup working on cultivated horse and st...	2019	http://artmeat.pro/	
Avant Meats	Avant is the first cultivated meat company i...	2018	https://www.avantmeats.c...	
Because Animals	Plant-based pet food	2016	https://becauseanimals.c...	
Bene Meat Technologies	We are developing the technology for cultiv...	2020	https://www.benemeat.co...	
BetterMilk	Quebec-based company producing cultivat...	2020	https://www.bettermilkno...	



“The first era of cultivated seafood and meat is drawing to a close. That period was characterized by companies clamoring to achieve proofs of concept and raise profiles to attract investment. The second era, which is upon us now, is about one thing: scale.”

—Wildtype, 2021 cultivated meat **pilot plant announcement**

Image credit: Wildtype

Partnerships

Collaborations with key research, production, and distribution partners are an essential step toward scaling the cultivated meat sector. Here are some of the year’s publicly announced partnerships:

- January 5: **Mitsubishi formed a partnership with Aleph Farms to sell cultivated beef in Japan.**

- January 29: **Avant Meats** formed a **strategic partnership** with **Vinh Hoan Corporation (VHC)**, the world's largest conventional pangasius company. The **partnership** will support Avant Meats' development and commercialization while diversifying VHC's product portfolio to appeal to a growing consumer base.
- February 2: **TurtleTree Labs** spun out **TurtleTree Scientific**, which is partnering with fermentation company **Dyadic** to produce growth factors and **China-based JSBiosciences** to develop cell culture media at commercial scale.
- March 4: Brazilian multinational **BRF** is **partnering with Aleph Farms to produce cultivated meat in Brazil**. Facilitated by GFI Brazil, the partnership will enable production of cultivated meat on a large scale and help BRF expand its product portfolio. BRF, the world's second-largest chicken producer and fifth-largest beef producer, expects to offer the product in supermarkets in 2024.
- March 8: **Avant Meats announced** a partnership with **QuaCell**, a Chinese biopharmaceutical company, to further reduce production costs.
- April 28: **BlueNalu formed a partnership with Thai Union and Mitsubishi**. This partnership will enable BlueNalu to conduct market research, assess regulatory requirements, and develop consumer insights to advance cultivated seafood in Asia.
- May 27: **Merck KGaA, Tufts University, and Technical University of Darmstadt** signed a **three-year collaboration agreement** to research bioreactor design.
- July 13: **Nestlé S.A. announced a partnership with Future Meat to bring hybrid plant-based and cultivated meat products to market**.
- July 21: **MeaTech and Israeli pork giant Tiv Ta'am formed a partnership to make cultivated meat**. The companies will jointly develop new products and construct a factory, with Tiv Ta'am retaining distribution and marketing rights.
- August 18: **IntegriCulture announced a joint R&D initiative with Maruha Nichiro**, one of the largest fishery companies in the world.
- September 13: **BlueNalu formed a partnership with Nomad Foods to bring cultivated seafood to Europe**. In the first partnership between a European consumer-packaged-goods company and a cultivated seafood company, Nomad and BlueNalu will collaborate on market research and consumer insights, regulatory approval, and product development.
- September 17: **DSM formed a partnership with cell-based startup Meatable to develop affordable growth media**.
- September 24: **Avant Meats and A*STAR's Bioprocessing Technology Institute collaborated to accelerate cultivated fish technology for the mass market**. The parties will establish the Joint Research Laboratory for Cultivated Fish Bioprocessing in Singapore to develop and optimize solutions for scalable production of cultivated fish cells.
- September 29: **Aleph Farms formed a partnership with two of Asia's largest food companies to bring cultivated meat to market**. Thailand-based conventional seafood company **Thai Union** and Korea-based food and bio company **CJ CheilJedang** will support Aleph with its strategy to scale-up and go to market in the Asia-Pacific region.

- December 8: **Aleph Farms** partnered with German chemical supplier **WACKER** to make **affordable animal-free cell-growth media more widely available**.



For a full list of companies with initiatives in cultivated meat and seafood, visit [this link](#).



“We consider cultivated meat as another alternative to available protein sources, to meet new consumer profiles. Production is carried out in bioreactors, from animal cells and emerged with the development of biotechnology in food production, bringing benefits to the production chain and advantages for the environment. We see meat substitutes as a growth driver—initiatives such as these will strengthen business diversification to meet growing consumer demands for a greater variety of alternative proteins.”

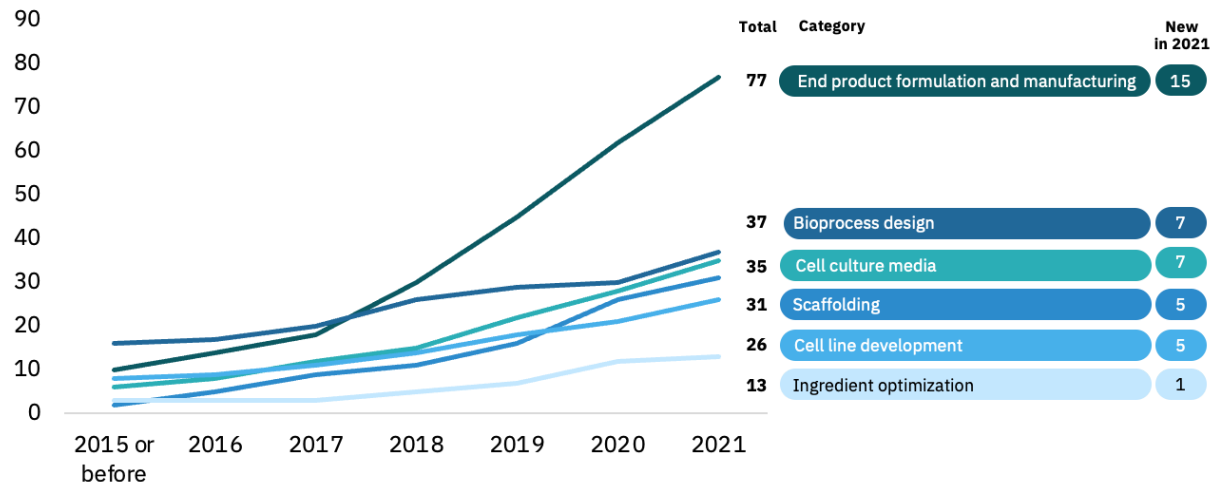
—Marcel Sacco, global VP for innovation, R&D and new business at BRF

Industry organizations

As the industry grows and matures, cultivated meat startups are increasingly keen to identify precompetitive areas where collaboration can accelerate progress for everyone. 2021 saw several industry organizations coalesce and grow, as well as established industry organizations for adjacent fields welcome cultivated meat companies as members:

- Shiok Meats took the lead in establishing the **APAC Society for Cellular Agriculture**, the first of its kind with a specific APAC focus.
- The Israel Innovation Authority launched an **Israeli cultivated meat consortium**.
- **AMPS Innovation** added members and increased its regulatory engagement efforts.
- IntegriCulture launched the **CulNet consortium in Japan to co-develop media and bioprocessing hardware**.
- The **Cultivated Meat Modeling Consortium** expanded its membership, which now includes companies along the cultivated meat value chain such as Merck KGaA, Darmstadt, Germany; Aleph Farms; and CellulaRevolution.
- **CellAg UK** launched to catalyze cultivated meat collaboration in the United Kingdom.
- The **Alternative Protein Council** in Australia launched in March 2021.
- **Cellular Agriculture Europe** launched and held its first general assembly meeting.
- GFI joined the **Advanced Regenerative Manufacturing Institute** to encourage cross-pollination between innovators in the cultivated meat and regenerative medicine sectors.

Figure 6: Cumulative number of companies by technology focus and year founded



While over 100 companies are squarely focused on cultivated meat or seafood, more than 60 additional companies have publicly announced formal projects or product/service offerings along the cultivated meat technology stack. Many of these companies are active in the life sciences industry and can provide critical inputs, infrastructure, and expertise to cultivated meat startups. This business-to-business (B2B) activity will be a valuable force multiplier for the industry, as these services and expertise will benefit multiple businesses rather than stay siloed in a single company.

In addition to technology milestones reached by vertically integrated cultivated meat companies, the advent of B2B products and services signals a maturing industry that will be better able to specialize and make progress instead of having multiple companies simultaneously solving the same challenges. A [report from Helikon Consulting](#) synthesizes alternative-protein market research and fundraising data to illustrate the importance of a specialized and scalable B2B ecosystem and outlines strategies for closing the funding gap. Notable technologically significant developments from 2021 include the following:

- January 21: South Korean startup DaNAgreen **launched low-cost 3D scaffolds**.
- July 21: UK-based Animal Alternative Technologies **developed a “renaissance farm” that uses AI to make cultivated meat**, including designing end-to-end cultivated meat processes with bioreactors run by automated software.
- August 25: **Unicorn Biotechnologies launched a fully automated manufacturing platform** designed to scale cellular agriculture that will be offered as a B2B service to cultivated meat companies.
- September 7: **MeaTech filed a U.S. patent for cultivated fat free of fetal bovine serum (FBS)**.

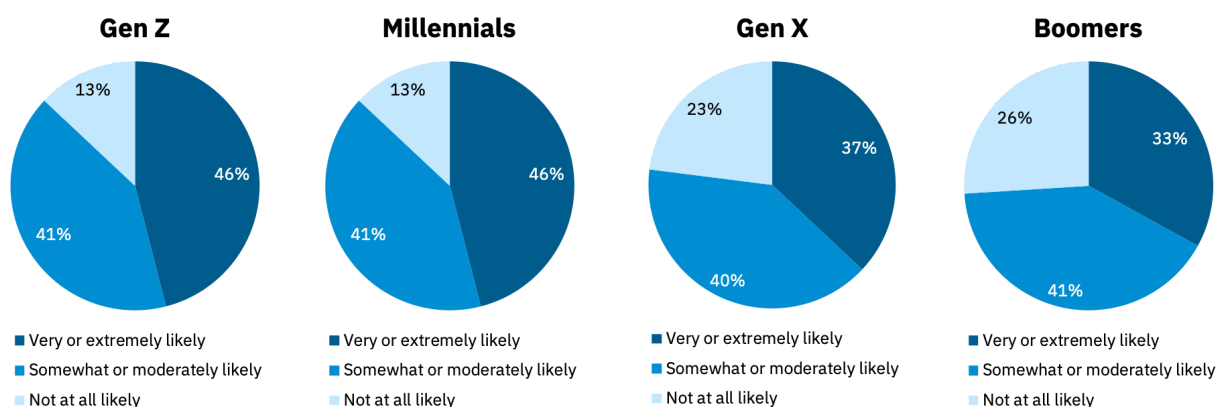
- September 30: **Algenex announced a new growth-factor line** aimed at cultivated meat production.
- October 18: **ProFuse Technology** launched in Israel as an academic spinoff that plans to commercialize new cell-differentiation technologies.
- October 19: **Culture Biosciences raised an \$80 million Series B for cloud-based bioreactors**. While mostly focused on fermentation technologies, Culture’s technology has the potential to streamline cultivated meat R&D scale-up.
- November 29: **Taimat Sciences utilized plant molecular farming to develop B2B cell culture media solutions**.
- November 30: **Biftek announced it was commercializing an animal-free growth medium**.
- December 8: UK-based life-sciences supplier AMSBIO **launched an alternative-protein business line**.
- December 10: **UPSIDE developed animal-free cell feed**.
- December 15: **South Korea’s CellMEAT produced a cell culture medium without FBS**.

Consumer insights

Industry and academic studies conducted and published in 2021 suggest promising levels of consumer interest in cultivated meat. Some highlights from consumer research are as follows:

- **U.S. and UK adoption of cultivated meat: A consumer segmentation study.** Younger generations in the United States had the greatest openness. Across both countries, 88 percent of Gen Z members were at least somewhat likely to try cultivated meat, followed by millennials, Gen Xers, and baby boomers at 85, 77, and 72 percent, respectively.

Figure 7: Openness to trying cultivated meat by generation



- **What U.S. consumers want in alternative seafood.** Thirty-five percent of respondents found cultivated seafood appealing, and 38 percent said they would consider purchasing it in the future. “Has good flavor” was the most important messaging attribute.

- **South African consumer adoption of plant-based and cultivated meat: A segmentation study.** Sixty percent of participants were highly likely to try cultivated meat, with 53 percent highly likely to purchase. The highest acceptance was among younger generations.
- GFI Brazil published a cultivated and plant-based meat **nomenclature study**. The study found that while “carne limpa” (“clean meat”) correlated with overall highest purchase intent, it was also less differentiating than other terms. The report authors recommend “carne cultivada” (“cultivated meat”) for clarity, consumer appeal, and consistency.
- **Chinese consumers’ attitudes and potential acceptance toward artificial meat.** Twenty percent of participants were willing to try cultivated meat, with food safety and nutrition as the top motivators.
- New Harvest published a **safety study** that featured a comprehensive overview of food safety considerations for cultivated meat.
- The consumer informational website **whatiscultivatedmeat.com** was launched.

Nomenclature use

Since the industry’s inception, companies and the media have used a wide variety of terms to refer to genuine animal meat produced by cultivating animal cells directly. Multiple consumer studies and corporate surveys have assessed consumer response on industry nomenclature, with data pointing to a small subset of terms rising to the top.

In 2021, nomenclature use continued to coalesce around specific terms for products derived from animal cell culture, with “cultivated” rising above others by a wide margin. A September 2021 GFI poll of company CEOs from 44 companies found that 75 percent preferred “cultivated.” Only one company participating in the survey preferred “cell-based,” a previous favorite.

Figure 8: Preferred nomenclature among CEOs of 44 companies in the industry

Term	Usage
Cultivated	75%
Cultured	20%
Cell-cultured	7%
Cell-based	2%

Note: Percentages do not add up to 100, as multiple selections were permitted.

Perspectives from the field

- “Cultivated meat is a bit friendlier, foodier, translates into some of our key European languages, and signals a bit more of the caring/precarious process needed to keep cells happy,” explained Tim van de Rijdt, chief business officer at Mosa Meat and president of Cellular Agriculture Europe. “Thus far, it’s also been the preferred modifier among the 13 members of Cellular Agriculture Europe.”
- “We agree that cultivated meat is the way to go, and aligning as a sector will help us all be more effective,” Aleph Farms CEO Didier Toubia said. “Based on the research we’ve performed, cultivated will fulfill the requirements for differentiating the product and appealing to consumers.”

Looking at websites, media statements, and public reports, we find a preference for “cultivated” among several top investors: **McKinsey**; the UC Davis **Cultivated Meat Consortium**; Bill Gates’s **Breakthrough Energy**; and **Alt-Meat**, the unofficial chronicler of all things alternative meat.

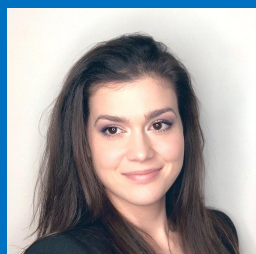
More than meat: Promising applications for animal cell technology

While animal cell culture in food is applied primarily to cultivated meat production, similar processes can be used to produce milk, gelatin, egg, and other components or end products. Among these applications, milk production is the most commercially advanced—three companies have publicly announced a focus in this domain, and in 2021, these companies raised a combined \$30 million in venture capital financing. Key developments include the following:

- Startups Biomilk, Wilk, and Me&Ma are focusing initially on human breast milk for infant nutrition.
- Caviar Biotech, a spinoff from animal-based caviar company Exmoor Caviar, is **applying animal cell culture technology to create sturgeon caviar**.
- **IntegriCulture** and **Avant Meats** are developing cell-cultured skincare ingredients.
- **Because Animals**, **Wild Earth**, and **Pristine Pet Food** are creating pet foods utilizing cultivated meat ingredients.
- **Dutch startup Geneus Biotech is producing cultivated fur**.

Like cultivated meat, emerging cell-culture applications could significantly disrupt the market for conventional products in their respective categories, should the technology prove scalable and economically viable.

Adjacent markets may also serve as high-value opportunities for market entry while still at relatively small scale and high cost, as shown in the examples above. Cultivated meat companies could launch skincare ingredients and other products en route to achieving food-appropriate scale and cost. While dairy, egg, and other end-product applications of animal cell culture are not the focus of this report, GFI will continue to evaluate the development of these potentially transformative subsectors and consider including them more substantively in future state of the industry reports.



“Public and private support for cultivated meat flourished in 2021 as the industry achieved several critical milestones. Upside Foods and Wildtype opened the first production facilities for cultivated meat in the United States, and for the first time in history, the USDA awarded a grant for cultivated meat research. Spearheaded by Dr. David Kaplan at Tufts University, a \$10 million award was distributed between Tufts, UC Davis, MIT, and other academic institutions. Future Meat Technologies also received the largest investment to date in the cultivated meat industry, raising a groundbreaking \$347 billion Series B.”

—Jess Krieger, founder and CEO at Ohayo Valley

Cultivated meat image library

News articles about cultivated meat often feature images of a pile of ground beef in a petri dish, held by a blue-gloved hand. These images are not effective at grounding the reader in an accurate vision of cultivated meat production. GFI’s **library of Creative Commons-licensed images of cultivated meat** seeks to advance a more authentic representation of these products and better position them as familiar and delicious.

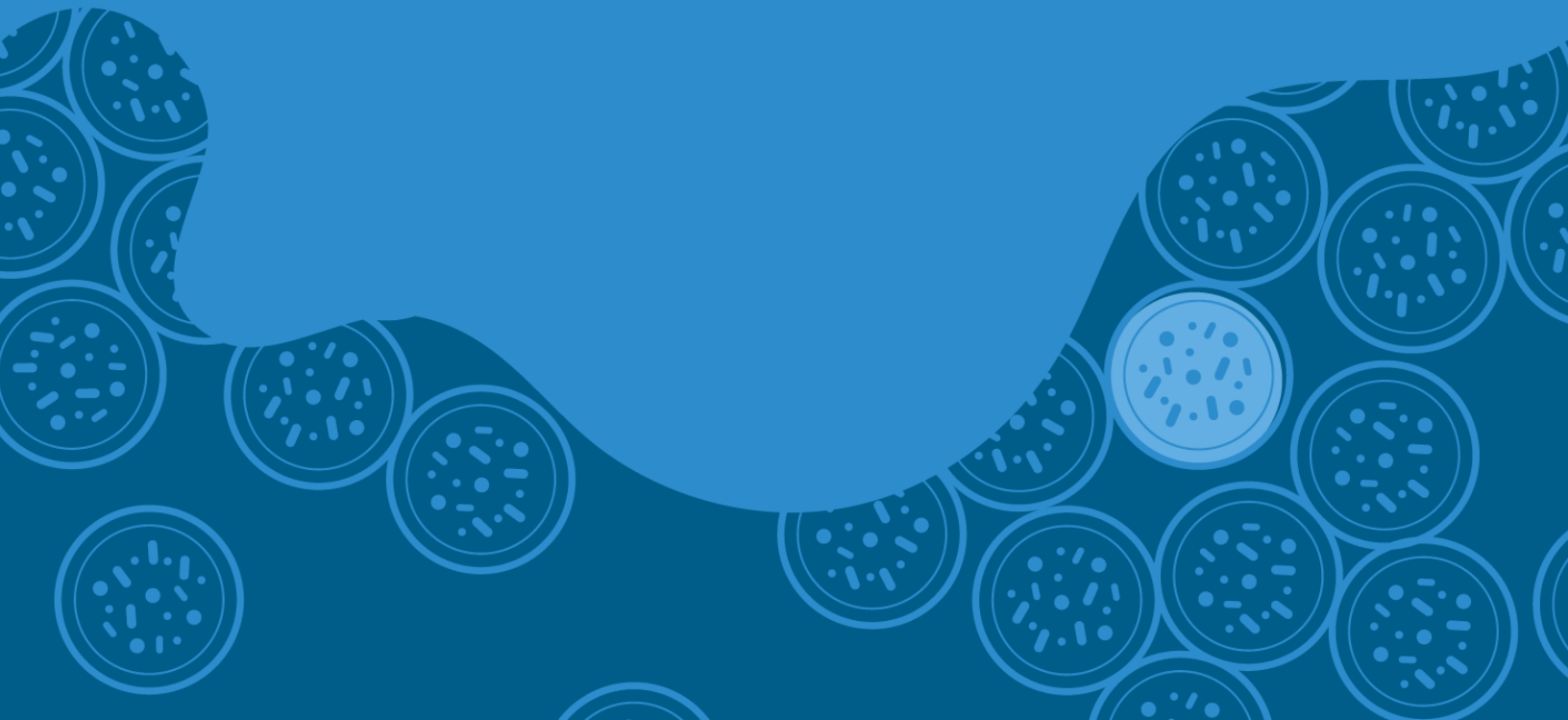


If you have images you’d like to contribute, **share your photos with us.**

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Section 2

Investments



Section 2: Investments

Overview

Cultivated meat investments continued their meteoric rise in 2021. If 2020 was a breakout year for the industry, 2021 solidified cultivated meat as a powerful ESG and growth theme in an increasing number of investors' portfolios. During the year, the industry's investor base grew by 62 percent to 458 unique investors. Supported by new and existing investors alike, cultivated meat companies raised \$1.38 billion last year. This brought total investment capital raised in the industry to at least \$1.93 billion. Regionally, Israel punched above its weight, accounting for more than a third of investments. We also saw the industry's first few liquidity events, indicative of its rapid maturation.

While 2020 brought the industry's first Series B funding round, 2021 added eight more growth-stage rounds (Series B or higher) to the tally. In addition to later stage raises, several notable influential deals occurred in emerging categories and countries:

- **Future Meat Technologies** closed out the year with a record-breaking **\$347 million Series B** round in December, led by ADM Ventures and joined by Tyson.
- **Eat Just** raised a **\$200 million Series F** round in March, followed by a **\$276 million** round completed in September.
- **Aleph Farms** raised \$100 million in a Series B round led by L Catterton and DisruptAD. Food and meat companies including Thai Union, BRF, Cargill, and CJ CheilJedang also participated in the round.
- Companies operating in China—one of the most critical regions for transforming the global protein system—are increasingly gaining recognition from investors. **Joese Future Food Co., Ltd.**, the first Chinese company to conduct cultivated meat R&D, announced it had raised ¥50 million (\$10.8 million) in a Series A funding round. Meanwhile, Shanghai-based **CellX** completed its second round of funding within a six-month period.
- South Africa-based **Mzansi Meat** raised the first Series B round by an alternative protein company in Africa, bringing in \$17 million in January.
- Cultivated seafood companies raised significant rounds, with **BlueNalu** raising \$60 million in convertible debt and **Finless Foods** raising a \$34 million Series B.

Meanwhile, nondilutive capital was nearly absent from cultivated meat company financing. In particular, no companies raised publicly disclosed debt. While this may be partially due to less frequent disclosure of debt financing, as well as the relative nascency of the industry's life cycle, nondilutive capital is a critical type of financing that companies will need to turn to in coming years. As companies shift into commercial-scale production by building or leasing manufacturing facilities and equipment, nondilutive capital—including various forms of debt,

project financing, and infrastructure and equipment leasing—may offer benefits over dilutive equity financing.

Although alternative protein investments have grown at an impressive rate, they remain a miniscule fraction of the trillions of dollars that have been invested globally in climate technology companies as a whole. In 2021 alone, private capital in earlier-stage climate technology companies amounted to \$47 billion.

Alternative proteins are just beginning to see a much-needed diversification of funding types and sources. As climate technology industries like renewable energy and electric vehicles have matured, they have attracted a wide array of investment beyond venture and private equity capital, including government funding, funding raised through public equity and debt markets, and project finance, that is not captured in the \$47 billion private capital total. Indeed, renewable energy and electric vehicle investments significantly overshadow alternative protein investments relative to the climate mitigation potential of each of these industries, which illustrates the underinvestment in alternative proteins as a climate solution.

Clearly, much more investment will be needed to help reach public and private net-zero commitments. Such investments will allow companies to continue critical R&D, scale production, and bring down costs to better compete with conventionally produced animal protein.

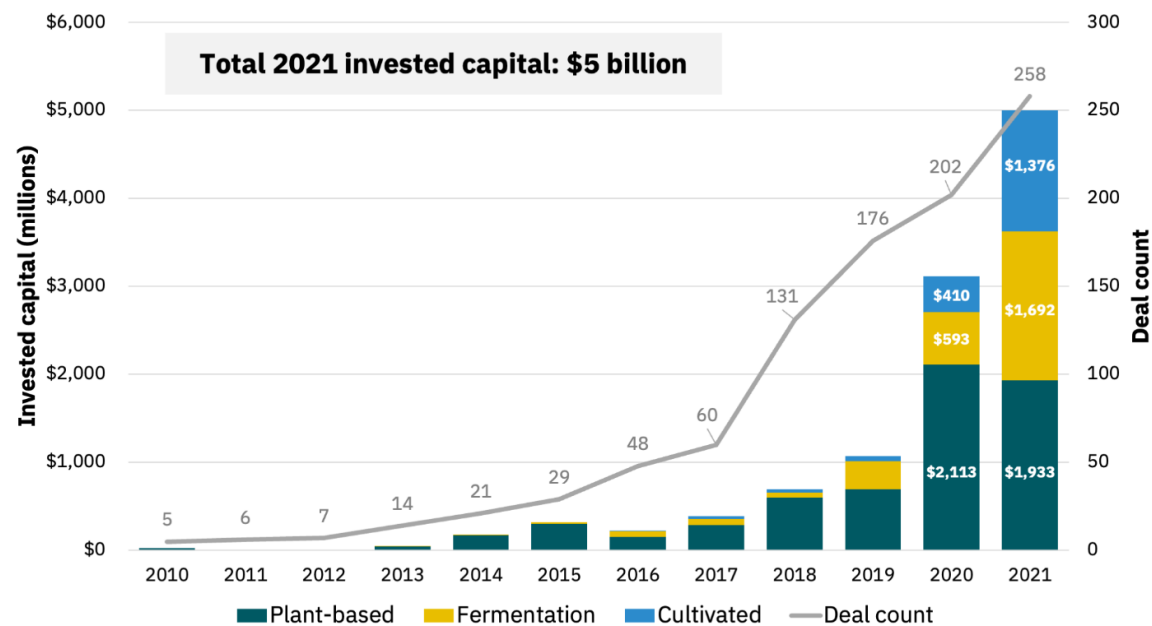
2021 investment overview

Invested capital	Largest investment	Unique investors
\$1.38 billion in 2021 (71% of all-time investment, up 336% from 2019) \$1.93 billion total (2016–2021)	\$347 million (Future Meat Technologies)	175 new in 2021 (60% growth from 2020) 453 total (2016–2021)
Invested capital deals	Growth stage deals (Series B and above)	Liquidity events
64 in 2021 188 total (2016–2021)	8 in 2021 9 total (2016–2021)	\$18.6 million in 2021 \$18.6 million total (2016–2021)

Source: GFI analysis of data from PitchBook.

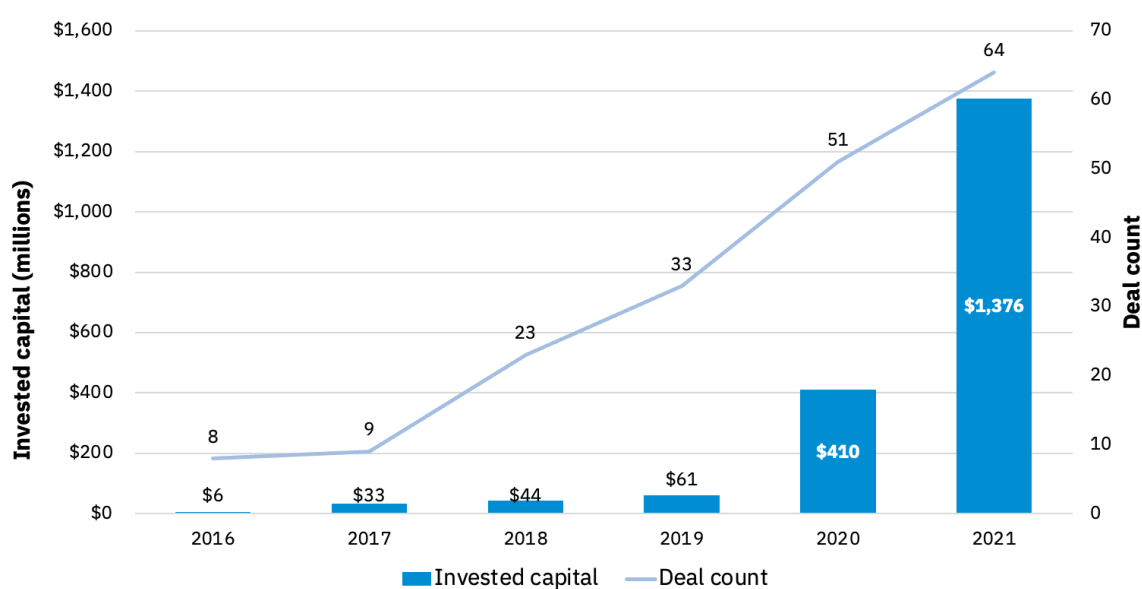
Note: Data has not been reviewed by PitchBook analysts. See the *Methodology of investment calculations* section for GFI's data collection methodology and definitions of "invested capital."

Figure 9: Annual alternative protein investment trend (2010–2021)



Source: GFI analysis of data from PitchBook.
Note: Data has not been reviewed by PitchBook analysts.

Figure 10: Annual investment in cultivated meat (2016–2021)



Source: GFI analysis of data from PitchBook.
Note: Data has not been reviewed by PitchBook analysts.

Methodology of investment calculations

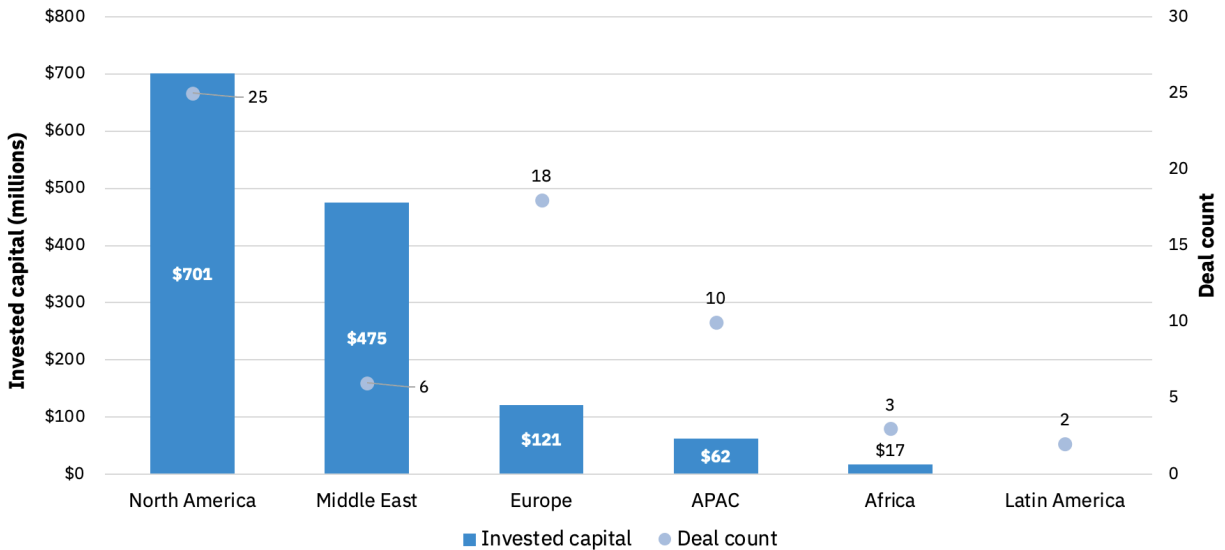
GFI conducted a global analysis of cultivated meat companies using data from PitchBook. Our analysis uses a list we custom-built in PitchBook of companies that focus primarily on cultivated meat or seafood products or on providing services to those who produce them. We excluded the many companies that are involved in meat cultivation but not as their core business, such as **Laurus Bio** (formerly Richcore Lifesciences), as the funding these companies devote to cultivated meat is undisclosed. We included cultivated milk and egg companies as well as cultivated meat pet food companies, though they are not the focus of this report. Some companies included in our list may also offer products or services that apply to another protein category. For example, **Cocuus** is included in our dataset, but its platform may also be used for plant-based meat. Meanwhile, the \$200 million **Eat Just** raised in March 2021 for use across its product lines and the \$267 million raised for its 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 at least half its business remains focused on plant-based egg products).

PitchBook profiled 92 cultivated meat companies, 68 of which have disclosed deals. Of these 68 companies, 61 have deals with publicly disclosed amounts. Because our aggregate calculations include only companies with deals and deal sizes disclosed to PitchBook, they are conservative estimates.

For the purposes of this report, *invested capital/investment* comprises accelerator and incubator funding, angel funding, seed funding, equity and product crowdfunding, early-stage venture capital, late-stage venture capital, private equity growth/expansion, capitalization, corporate venture, joint venture, convertible debt, and general debt completed deals. *Liquidity events* comprise completed mergers, acquisitions, reverse mergers, buyouts, leveraged buyouts, 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.

Please note that the figures published in this report may differ from prior figures published by GFI as we continually improve our dataset.

Figure 11: Investments in cultivated meat by region (2021)



Source: GFI analysis of data from PitchBook.

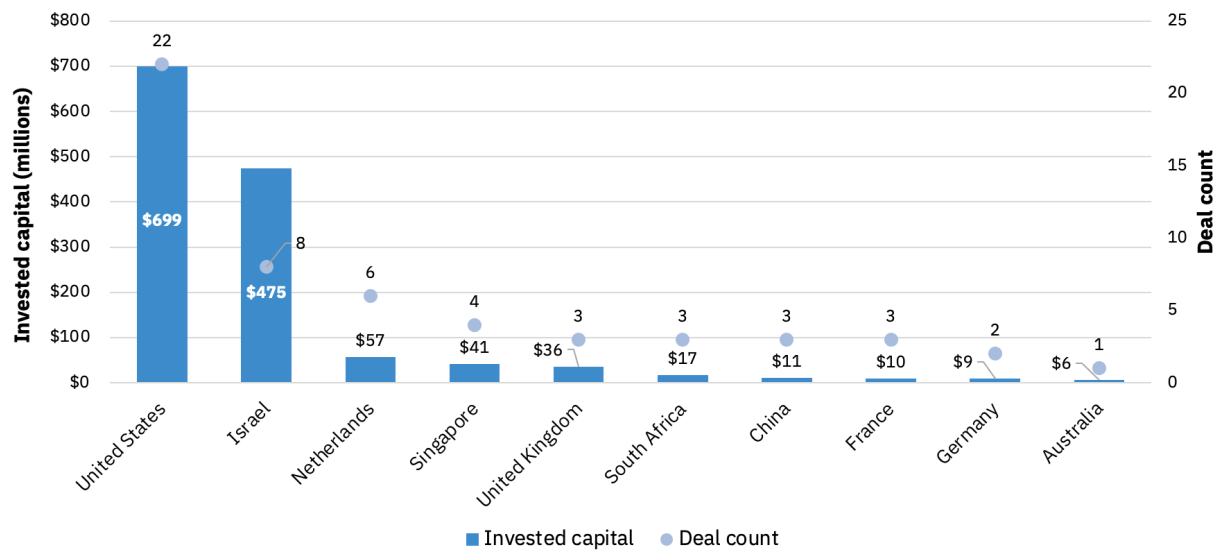
Note: Data has not been reviewed by PitchBook analysts. North America includes Canada and the United States only. Latin America includes Mexico, as well as South American and Central American countries.



“We see cultivated meat as well placed to contribute to the alternative protein landscape, with regulatory momentum and additional financing activity driving the emergence of new entrants across the entire value chain. Capex remains a significant barrier to entry, though we have been encouraged by the growing interest in manufacturing licensing and the number of filed patents relating to culture medium.”

—Hiral Patel, head of sustainable and thematic investing in equity research at Barclays

Figure 12: Investments in cultivated meat: Top 10 countries (2021)



Source: GFI analysis of data from PitchBook.

Note: Data has not been reviewed by PitchBook analysts. We are aware of additional investments in these countries, including China, that are not captured by our methodology.

Deal type summary statistics (2016–2021)

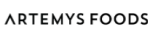
Deal type	Median	Minimum	Maximum	Count
Seed	\$3.1M	\$0.2M	\$12.4M	59
Series 1, 2	\$6.6M	\$0.6M	\$75M	6
Early stage VC (uncategorized)	\$3M	\$440K	\$60M	23
Series A, A1, A2	\$12.6M	\$2.4M	\$47M	21
Series B, B1	\$41.3M	\$1.7M	\$347M	7
Series F ¹	\$233.5M	\$200M	\$267M	2

Source: GFI analysis of data from PitchBook.

Note: Data has not been reviewed by PitchBook 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 and corporate rounds. It also excludes uncategorized rounds.

¹ The Series F rounds are those of Eat Just.

Figure 13: 2021 key funding rounds

Series F		Series B/B1				
						
\$267M	\$200M	\$347M	\$100M	\$34M	\$26.8M	\$17M
Series A						
						
\$47	\$30M	\$25M	\$24M	\$22M	\$21M	\$15.5M
						
\$10.8M						
Early Stage VC						
						
\$60M	\$22.3M	\$10M				
Seed						
						
\$10M	\$8.4M	\$6.7M	\$6M	\$5M		

Record raises

Future Meat Series B raise

In a record-breaking deal, Future Meat Technologies raised a \$347 million Series B round in December. The Israeli company plans to build a production facility in the United States and aims to have a product on shelves in late 2022, pending regulatory approval.

Among other investors, both ADM Ventures and Tyson Foods participated in the funding round. The strong involvement of some of the world's biggest food companies signals a vote of confidence in the cultivated meat industry and can help startups accelerate pace of growth.

Investment spotlight: BlueNalu

Blowing all prior cultivated seafood deals out of the water, BlueNalu raised \$60 million of convertible debt in 2021. It was the fourth-largest deal of the year, behind only amounts raised by Future Meat and Eat Just. The deal enabled BlueNalu to launch the world's first commercial pilot facility for cultivated seafood. The 40,000-square-foot facility will support BlueNalu in its plans for market launch.

Most active investors in 2021

Investor	Logo	Investor type	Headquarters	2021 deal count	Total deal count
SOSV / IndieBio		Venture capital	Princeton, USA / San Francisco, USA	8	21
CPT Capital		Venture capital	London, United Kingdom	7	15
Big Idea Ventures		Venture capital	New York, USA	5	12
CULT Food Science		Venture capital		5	6
Siddhi Capital		Venture capital	Cherry Hill, USA	5	7
Agronomics		Venture capital	Douglas, United Kingdom	4	11

Prithvi Ventures		Impact Investing	Albany, USA	4	5
Alumni Ventures Group		Venture capital	Manchester, USA	3	4
Blue Horizon		Venture capital	Zürich, Switzerland	3	8
Manta Ray Ventures		Venture capital	London, United Kingdom	3	4
Sand Hill Angels*		Angel Group	Mountain View, USA	3	3
Sustainable Food Ventures		Venture capital	Raleigh, USA	3	4
Y Combinator		Accelerator / incubator	Mountain View, USA	3	6

Source: GFI analysis of data from PitchBook Data.

Note: Data has not been reviewed by PitchBook analysts. "Most active investors in 2021" includes any organization that made three or more publicly disclosed investments in a cultivated meat company during calendar year 2021.

*Indicates companies that made disclosed investments in cultivated meat or dairy for the first time in 2021.

Liquidity events

Liquidity events—also known as exits, representing the sale of an equity owner's interest in a company typically through a merger, acquisition, buyout, or IPO—have arisen in the cultivated meat industry faster than one might have expected. Only five years after the first dollars began flowing to recently launched cultivated meat companies and with the vast majority of companies still pre-revenue, we saw a couple of acquisitions and a public listing. Three deals were disclosed in 2021:

- **Wilk (formerly Biomilk)** became the world's first publicly traded cultivated milk company when it went public on the Tel Aviv stock exchange via a merger deal with Fantasy Network, a publicly traded shell corporation.
- Cultivated fat producer **Peace of Meat** was acquired by Israeli publicly listed cultivated meat company **MeaTech** for approximately \$19 million.

- Singapore-based **Gaia Foods**, which is working to produce cultivated red meat, was acquired by neighboring cultivated seafood specialist **Shiok Meats** for an undisclosed amount.

Consolidation among cultivated meat startups is promising and indicative of healthy industry development. Acquisitions reduce the number of duplicative early-stage companies and inefficient business structures across the industry, enabling acquisition targets with valuable intellectual property, trade secrets, and talent—but a weaker business position or too short a financing runway—to be compensated for their efforts. Consolidation also facilitates faster R&D and scaling by acquirers through inorganic growth.



“JBS' investment is justified by the growing demand for protein. By 2050, the world's population will be nearly 10 billion people. That's 2 billion more mouths to feed. This means there will certainly be room for alternative production methods, including plant-based products. We have been monitoring the cultivated protein segment for the past few years before deciding to make our most recent moves. Our strategy is to accelerate innovation, combining technological know-how and production capacity. By diversifying our portfolios to meet the needs and preferences of the consumer, we will strengthen our position as a global leader in the production of protein-based foods.”

—Eduardo Noronha, Global Head of HR and Operational Excellence, JBS

Cultivated meat companies are not only being acquired by their peers but also by industry incumbents. While the deal did not close in 2021, JBS—the world's largest meat company—reached a definitive agreement to acquire BioTech Foods for approximately \$41 million in November 2021. Demonstrating the capital, scale, and operational advantages industry incumbents can bring to bear, JBS announced plans to build a new production plant in Spain for BioTech Foods. The company also plans to launch a cultivated meat R&D center in Brazil. We expect to see an acceleration of acquisitions and other liquidity events in the year ahead.

Other financing

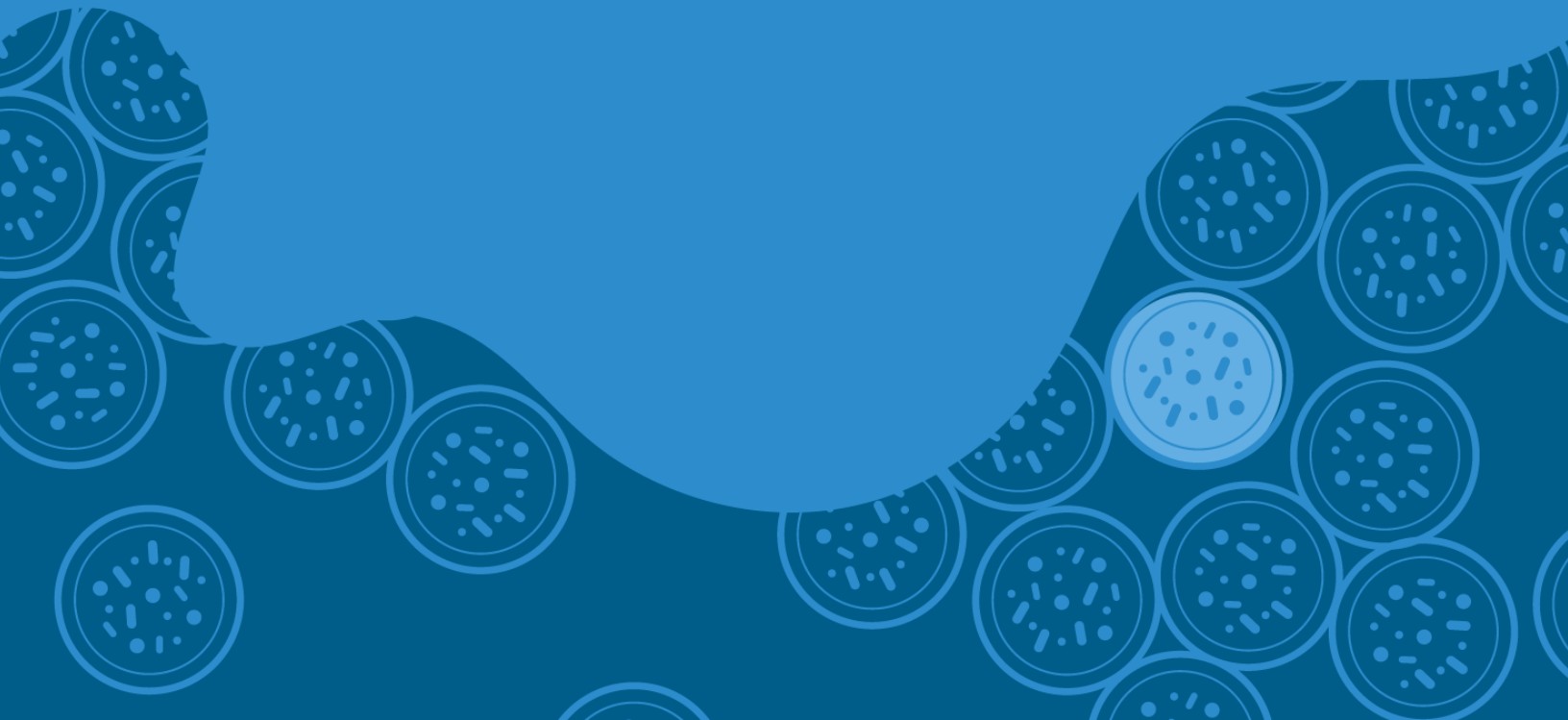
In addition to more traditional financing methods, some public companies pursue financing paths such as subsequent public share offerings and private investment in public equity (PIPE) deals. Among cultivated meat companies in 2021, such activity was limited to MeaTech. The company, already publicly traded on the Tel Aviv stock exchange, raised \$25 million in a second public offering on the Nasdaq stock exchange in March 2021.

The Good Food Institute is not a licensed investment or financial advisor, and nothing in the state of the industry report is intended or should be construed as investment advice.

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Section 3

Science and technology



Section 3: Science and technology

Overview

Across the cultivated meat ecosystem, scientific and technological progress accelerated in 2021. Several studies and expert analyses helped stakeholders in the field understand the magnitude of the challenge of achieving economically viable and environmentally friendly cultivated meat at scale while pinpointing discrete high-leverage opportunities for innovations to address cost and environmental impact. The number of research teams actively working on cultivated meat throughout academia and industry grew, as did the foundational knowledge necessary to transform how meat is made. This section discusses some of the key scientific advancements and signals of 2021.



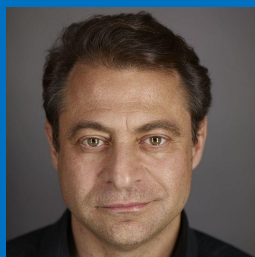
For a comprehensive introduction to the current state of the science in cultivated meat, visit GFI's [science of cultivated meat](#) page.

Techno-economics

Techno-economic assessments (TEAs) can help identify the cost drivers for commercial production of goods such as cultivated meat. In late 2020 and early 2021, three TEAs analyzing hypothetical commercial-scale cultivated meat production were published ([Humbird, 2020](#), and [2021](#); [Vergeer, 2021](#); and [Risner, 2021](#)). Additional resources comparing these studies were developed by [researchers at ReThink Priorities](#), demonstrating the value of having multiple independent analyses that utilize differing assumptions and process models to assess an emergent industry for which no commercial-scale facilities yet exist.

Subsequent media coverage in [The Counter](#) drew upon findings from some of these TEAs to highlight the challenges associated with cost reduction and scale-up facing the cultivated meat industry. [Discussions](#) ensued [online](#) about the economic viability of commercial cultivated meat production, with stakeholders from across sectors weighing in, from [academics](#) and nonprofit [leaders](#) to [scientists](#) and cultivated [meat companies](#). This robust discourse enhanced knowledge sharing and led to a more thorough and nuanced understanding of the unknowns, assumptions, challenges, and opportunities in the field.

GFI's team of scientists also shared their perspectives, highlighting the importance of TEAs in [providing a roadmap for research prioritization](#) rather than interpreting the findings as definitive predictions at this nascent stage of industry development. While the TEAs underscore the need for major scientific and engineering advancements in cultivated meat production, we [remain optimistic](#) that these challenges can be addressed with sufficient support of public and private research, enabling policies and infrastructure development.



“Billions of individuals desire and will continue to desire higher quality protein as a food source, but the earth is incapable of providing this with traditional livestock. A much more sustainable, scalable methodology is required.”

—Peter Diamandis, XPRIZE founder and executive chairman, in an [April 2021 announcement](#)

Ongoing research across the technology stack

Companies and **academic laboratories** continue to push the boundaries of cultivated meat research. Thanks to a small set of generous donors, GFI awarded research grants for **22 innovative projects** related to cultivated meat in 2021. See below for select highlights from our grantees across the technology stack.



Cell lines

Definition: For cultivated meat and seafood to fully 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 a restricted set of cell types. 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.

Learn more about cell lines in this [review article](#) published by GFI grantee Masatoshi Suzuki.

2021 research highlights: Teams led by GFI grantees **Dr. Gareth Sullivan**, **Dr. David Kaplan**, and **Dr. Ori Bar-Nur** made progress developing cell lines from Atlantic salmon, cows, and pigs, respectively. A team led by **Dr. Kevan Main** and **Dr. Cathy Walsh** at Mote Marine Laboratory was awarded a second grant to continue the development and characterization of cell lines from shrimp, Almaco jack, and redfish. GFI also awarded a grant to **Dr. Mukunda Goswami** for the development of a cell line from rohu (a type of carp popular in India), and we funded four additional projects focused on developing continuous muscle cell lines from poultry and fish through our **white space collaborations program**.

Outside GFI, researchers at Aarhus University **investigated** the impacts of storage time on cell viability and myogenic potential (the ability to form skeletal muscle tissue) and found that bovine

tissues stored for several days under appropriate conditions could still be used to isolate viable myogenic cells. Originally **published** in 2006 by Drs. Francesco Buonocore and Giuseppe Scapigliati of the University of Tuscia, an embryonic cell line from European sea bass was made **available** this year through the Kerafast cell banking repository and is being used by several cultivated seafood research teams. Singapore's A*STAR **announced** they were funding cultivated meat research through their new CRISP Meats program (CentRe of Innovation for Sustainable banking and Production of cultivated Meats). One focus of the new center will be the development and banking of cell lines from food-relevant species. An article in *WIRED UK* **highlighted** the challenges posed by the current lack of open-access cell lines for cultivated meat.



Cell culture media

Definition: Cell culture media contains the nutrients and growth factors needed to cultivate cells outside the body. **Cell culture media is a large cost driver of cultivated meat**, and extensive research efforts are underway to replace high-cost ingredients with more affordable, animal-free food-grade ingredients.

2021 research highlights: Progress toward lowering costs and creating serum-free formulations include announcements that Mosa Meat's team reduced their fat medium cost by **98 percent**; UPSIDE Foods and CellMEAT developed **animal-component-free and serum-free media**, respectively; and researchers at Tufts University developed a simple **serum-free medium** for the cultivation of bovine muscle cells, derived from the B8 media formulation sold by Defined Bioscience. A research team at the Weizmann Institute discovered a **cellular pathway** that leads to rapid muscle cell differentiation and spun out ProFuse Technology to commercialize the findings in the cultivated meat industry. Additionally, Aleph Farms announced a nonexclusive agreement with WACKER to manufacture and supply the industry with **growth factor proteins** that can help other researchers and companies replace the serum needed for their cell culture media formulations.

Gain more insights on cell culture media and growth factor trends in the cultivated meat industry by reading our **industry survey**, featuring data collected from 40 companies.



Scaffolding

Definition: 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 identification of the best materials (or combinations of materials) and development of innovative manufacturing technologies for scalable and cost-effective scaffolds.

Learn more about scaffolding in this 2021 **review article** published by a team of GFI scientists and research fellows.

2021 research highlights: Ongoing GFI-funded scaffolding work continued under the leadership of **Dr. Amy Rowat**, **Dr. Marcelle Machluf**, **Dr. Sara Oliveira**, and **Dr. Masatoshi Suzuki**. The focus of GFI's Competitive Research Grants program for 2021 was on whole-cut products, making scaffolding

a major focus of many newly funded projects. These included **Dr. Aline Bruna da Silva's** and **Dr. Vivian Feddern's** work on scaffolds for cultivated chicken, **Dr. Kelly Schultz's** work on hybrid hydrogel-based scaffolds, **Dr. Nataraja Yadavalli's** work on nanofiber scaffolds for shrimp, and **Dr. Frederico Ferreira's** work on algae-based scaffolds for sea bass (you can read more about the work of Dr. Ferreira's team [here](#)).

Outside GFI, two research teams based in Japan reported successful fabrication of small-scale cultivated meat prototypes using **bioprinting** and **stacked hydrogels**. Both projects received funding from the Japanese government's **JST-Mirai** program. Other labs demonstrated how materials such as **grass**, **spinach**, **nanocellulose**, and even **homemade bread** could be used as scaffolds for cultivated meat applications.



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 a spectrum of cultivated meat product types. [Learn more about bioprocess design.](#)

2021 research highlights: Researchers are beginning to address various aspects of bioprocess scale-up strategies for cultivated meat. In 2021, researchers at Aston University **published a study on the scale-up of bovine adipose cells** and Merck KGaA in Darmstadt, Germany, **announced funding for two projects at Tufts University and TU Darmstadt** aiming to apply textile bioengineering and screen-printing technologies to cultivated meat manufacturing. New companies with an explicit focus on bioprocess design and equipment development kicked off their activities in 2021, including **Unicorn Biotechnologies** and **Ark Biotech**.

To tackle scale-up challenges, public-private consortia have also formed, including multiple ongoing projects within the **Cultivated Meat Modeling Consortium** and the **CulNet consortium announced in Japan**. In 2021, GFI joined the **Advanced Regenerative Manufacturing Institute** to encourage cross-pollination between innovators in the cultivated meat and regenerative medicine sectors.



Check out our [research grants](#) page to explore grant opportunities and meet the scientists leading open-access cultivated meat research. GFI also highlights external funding opportunities via our [research funding database](#).



“The GFI two-year research grant that was granted to us in 2019 opened the door to my research in cultivated meat, which ultimately led to founding a startup company, Meatafora. Since I embarked on the GFI-funded research, the field of clean meat has led to new ideas for harnessing different aspects of my tissue engineering research background for the cultivated meat field.”

—Marcelle Machluf, founder, Meatafora

Research progress on environmental and socioeconomic impacts and food safety

Several studies published in 2021 increased our understanding of the environmental and socioeconomic impacts of cultivated meat technology, as well as reinforced the importance of food safety.

- **Environmental impact:** With funding from GFI, the research firm CE Delft published a **life-cycle assessment (LCA) of commercial cultivated meat production** in collaboration with more than 15 companies involved in the supply chain as well as Singapore’s science research agency A*STAR. The LCA found that cultivated meat could have massive environmental benefits compared with conventional meat, especially when sustainable energy is used in production. View a webinar overview of results and a summary of GFI’s policy recommendations based on the LCA data [here](#), and read this **review** by researchers at Ghent University to get caught up on all cultivated meat LCAs to date.

Environmental impact comparison between cultivated meat produced with renewable energy and ambitious benchmarks for conventional meat

	Cultivated meat compared with conventional chicken	Cultivated meat compared with conventional pork	Cultivated meat compared with conventional beef
Carbon footprint	17% reduction	52% reduction	Up to 92% reduction ¹
Land use	63% reduction	72% reduction	Up to 95% reduction ¹

¹ This varies according to whether comparisons are with beef from dairy cattle or with beef from cattle raised exclusively for meat.

- **Socioeconomic impact:** Researchers at the University of Colorado Boulder and The Breakthrough Institute summarized the **social and economic opportunities and**

challenges related to cultivated meat for rural producers in the United States.

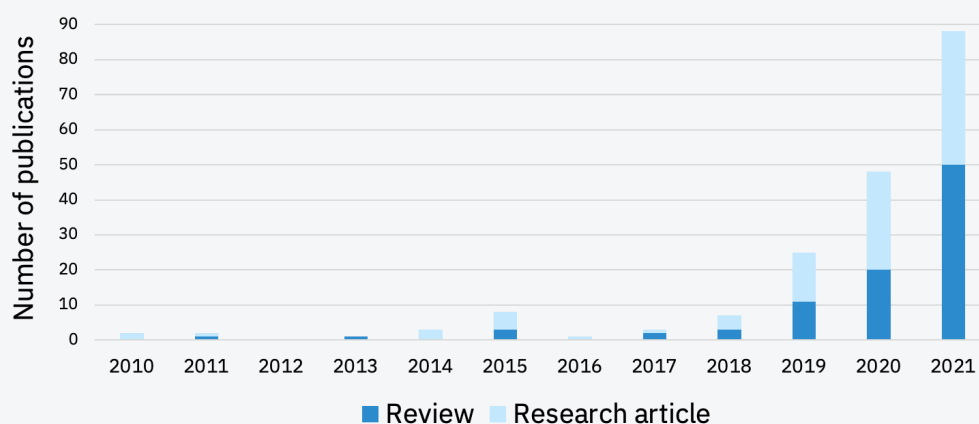
Additionally, **a UK-focused report** was published by researchers at Oxford Economics and UK-based cultivated meat company Ivy Farm, while Ontario Genomics led an effort to characterize the **opportunity for cellular agriculture in Canada**.

- These reports underscore that smart policies, especially those related to regulation, will be needed to capitalize on cultivated meat’s potential to contribute to economic growth, create new job opportunities, and build a more secure, diversified food supply.
- **Food safety:** Cultivated seafood company BlueNalu **highlighted the importance of implementing global best practices** for quality and safety of cultivated meat and seafood products. This call was heard by New Harvest and Vireo Advisors, who published **a detailed paper** mapping key food safety considerations and research priorities for the industry.
 - These writings call out the need to fill data gaps, develop standards, and increase harmonization between regulatory guidance and frameworks being developed by governments around the world.

A flurry of scientific discussion

Research into cultivated meat ramped up in 2021. GFI’s science and technology team has been tracking scientific publications focused on cultivated meat, and every year we see the numbers rise. We plan to release our library as a public resource in early 2022—stay tuned!

Figure 14: Papers about cultivated meat



Source: GFI

Note: Reviews refer to analyses of previously published work, whereas research articles refer to newly conducted experimental work.

USDA funds center of excellence in cellular agriculture

In October, the USDA **announced** it had awarded \$10 million to a team of researchers led by Dr. David Kaplan of Tufts University and Dr. Reza Ovissipour of Virginia Tech for the creation of a center of excellence in cellular agriculture at Tufts University. UC Davis, University of Massachusetts Boston, MIT, and Virginia State are also part of the new center, which will serve as a valuable hub for research and training. Additionally, GFI grantee Amy Rowat was **awarded** an Agriculture and Food Research Initiative grant from the USDA to establish cultured beef prototypes using tunable microcarrier scaffolds. These grants, which mark the USDA's first significant investments in cultivated meat and the U.S. government's largest to date, are a positive sign for the future of public funding for alternative protein research.

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 2021 include the following:

- **Scientific summaries.** GFI's **science of cultivated meat** page summarizes the state of the science and describes areas for future research. Deep-dive pages on each of the four main technology areas (cell lines, culture media, bioprocess design, and scaffolding) provide a more in-depth discussion.
- **Cell lines.** GFI continues work to **expand access to cell lines**. In 2021, we released a public tracker of known cell lines. This includes those that are available from public repositories, those that have been published in academic journals but are only available by contacting the cell line owner directly, and some that are still in development. If your lab or company is searching for cell lines, this is a great place to start. And of course, if you have developed a cell line you're considering sharing with the broader cellular agriculture community, **we'd love to talk with you**.
- **Tracking research grants.** We maintain a **research grants tracker** to help stakeholders better understand the landscape of open-access funding for alternative protein research. This includes data on the types of entities that fund alternative protein research, the breakdown of how much funding goes to each of the three pillars, and the geographical spread of funding. If you're looking for open funding opportunities, check out our **funding database**.
- **Collaborative researcher directory.** GFI maintains a **database of researchers** who are open to collaboration on alternative protein projects to ease the process of finding potential collaborators. For a comprehensive list

of scientific laboratories already actively involved in alternative protein research, see GFI’s [scientific research database](#).

- **Solutions database.** In 2021, we continued to add content to our [solutions database](#). This resource captures ideas for research projects, commercial ventures, or ecosystem solutions that have the potential to accelerate development and commercialization of alternative proteins. If you’re looking to get involved or looking for a new project, you may find some ideas here.



“In 2021 we saw the cultivated meat industry accelerate on essentially all fronts—research, funding, company creation, and buildout of the first production platforms for many companies. The most significant development we have seen in 2021 is the sheer number of meaningfully funded small and medium sized companies developing production platforms at the pilot and demonstration plant scales for themselves. The activity is reminiscent of the early days of replacement animal proteins where costs were very high and production levels small. Still the industry proceeded undaunted, scaled, and drove costs down in concert with broad market acceptance and growth.”

—John Ellersick, president at Next Rung Technology

Conferences and courses expand

Multiple flagship conferences continued to focus on cultivated meat by holding virtual events in 2021, including [Industrializing Cell Based Meats](#), the [Cultured Meat Symposium](#), the [International Cultivated Meat Conference](#), the [Emerging Meat Alternatives Conference](#), the [Stem Cell Society Singapore Symposium](#), and the [Good Food Conference](#).



Visit GFI’s [YouTube channel](#) to catch up on many of the sessions from 2021’s Good Food Conference.

Additionally, cultivated meat made its way into the discussion at new life sciences conferences and sessions, such as a four-part session focused on **stem cells and global sustainability** hosted by the International Society for Stem Cell Research, and sessions at the **International Life Sciences Institute** and **Society for In Vitro Biology** annual meetings.



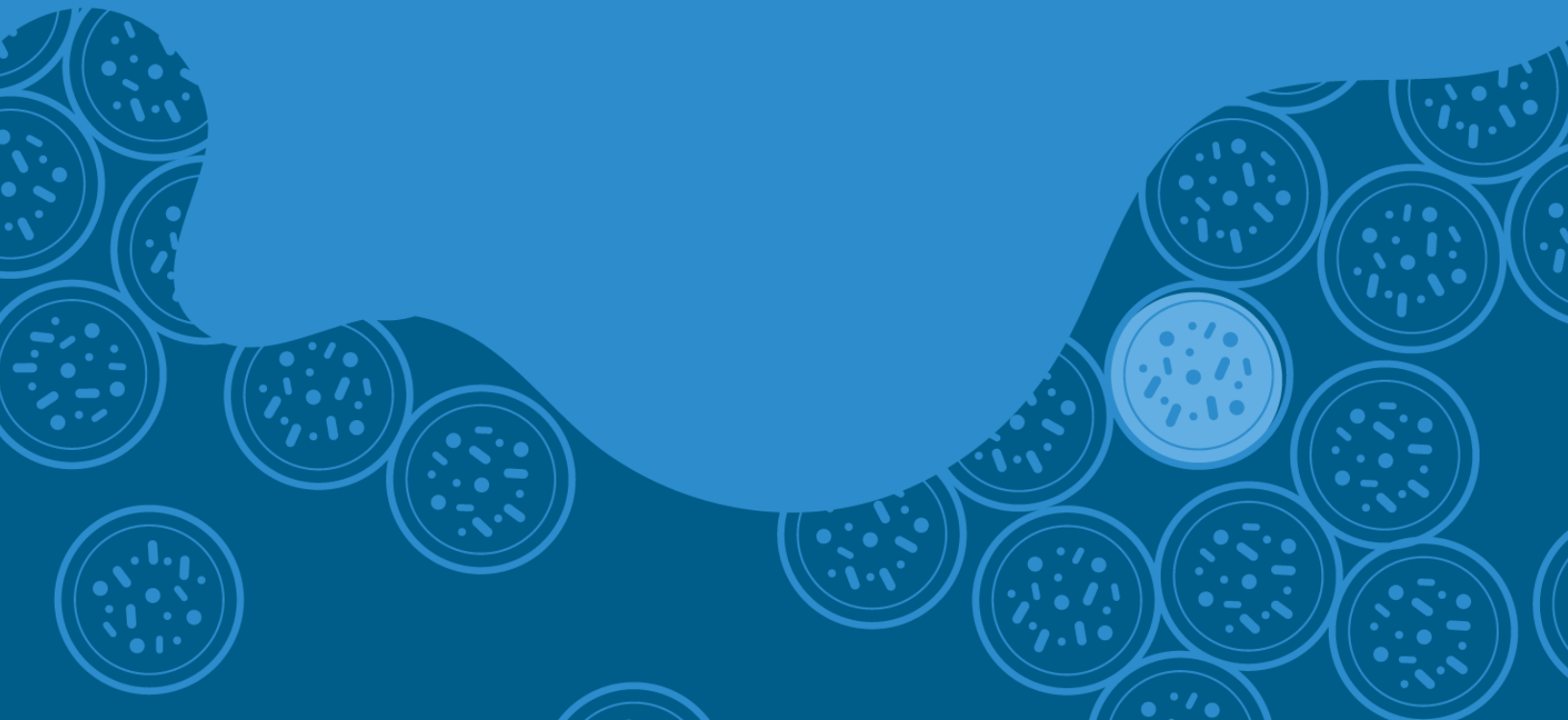
This year, we updated our free massive open online course (**MOOC**)—first launched in 2019—with new content on all three alternative protein pillars. If you’re new to alternative proteins, or if you could use a refresher, this would be a great time to sign up. Did we mention it’s free?

Several global alt-protein courses were launched or designed in 2021 to educate and train the industry’s future workforce. These included courses at **Nanyang Technological University**, the **National University of Singapore**, **UC Davis**, **UNC Chapel Hill**, **Stanford University**, **Johns Hopkins University**, and **Tufts University**. Many of these initiatives were led by the student groups of **GFI’s Alt Protein Project**. Students and instructors who are interested in developing new courses can visit GFI’s **curriculum repository**.

Are we missing something? Did we get something wrong? We’d appreciate your feedback via [this form](#).

Section 4

Government and regulation



Section 4: Government and regulation

The sale of cultivated meat and seafood depends on a clear regulatory path to market. Companies and governments must work together to successfully develop effective regulatory regimes. As of December 2021, Singapore remains the only nation to have approved the sale of a cultivated meat product. But other countries are making strides in the race to approve and invest in these products. Governments recognizing the global importance of cultivated meat are also starting to invest in research and development through grants and other funding programs. Below we outline regulatory and legislative progress in countries and regions that have taken steps forward in 2021.



European Union

Cultivated meat—when produced without genetic modification—is regulated under the European Union’s **novel food regulation**. Companies must apply to the European Commission for premarket authorization of their products. The authorization procedure includes a safety evaluation by the European Food Safety Authority (EFSA). Premarket authorization is handled centrally, meaning that once the European Commission and representatives from the EU member states approve a product, the approval applies across all 27 member states.

New **EU transparency rules** came into effect in March 2021 and allow for limited presubmission consultations between companies and EFSA. Additionally, companies seeking to apply for novel foods authorization are required to notify EFSA of any study commissioned in preparation of an application.

The European Union has also started to invest in alternative proteins. In October 2021, REACT-EU, a government funding program launched in response to the Covid-19 pandemic, awarded cultivated meat company Mosa Meat and partner Nutreco a €2 million grant for research into lowering the cost of cell culture media.

Similarly, in June 2021, Horizon Europe—the European Union’s main research and innovation program—**announced** three calls for proposals totaling €32 million in funding for research into alternative proteins, including cultivated meat.

EU member states have also ramped up public investment. In January 2021, the Spanish government granted €5.2 million (\$6.3 million) to BioTech Foods to investigate the health

benefits of cultivated meat. The Belgian and Dutch governments have also provided funding in prior years.



United Kingdom

With its exit from the European Union at the end of January 2021, the United Kingdom is no longer participating in the European Union’s common regulatory approval process. Any cultivated meat company wanting to sell their products in the United Kingdom must apply for authorization to the UK Food Standards Agency (FSA). But so far, the United Kingdom has adopted the most relevant aspects of EU food safety law into UK law, meaning there has been no significant change to the content of the risk-assessment procedure. The FSA provides **guidance** on how to submit an application.

The United Kingdom also invested in the sector in 2021. Innovate UK, a public organization funded by the UK government, awarded a grant of £106,000 to growth media company Multus Media in early 2021. In November, the United Kingdom granted Edinburgh-based Roslin Technologies £1 million to develop and commercialize stem cell lines that will help other companies produce cultivated meat.



“It is fantastic to see that the UK has recognized the potential of cultivated meat [and is eager to support local innovation]. With the UK’s funding we are accelerating our progress in our multi-species portfolio, scale-up and media development [for our cells], and the next generation cells [that grow faster and more efficiently].”

—Ernst Van Orsouw, CEO at Roslin Tech



Brazil

In Brazil, the General Food Office at the National Health Agency (ANVISA) and the Animal Products Inspection Department, under the Ministry of Agriculture, will be responsible for reviewing applications for approval of cultivated meat products.

ANVISA is committed to understanding the food safety and labeling challenges posed by cultivated meat and is in the process of developing a regulatory framework that would cover cultivated meat products. Throughout 2021, GFI Brazil promoted discussions on regulatory best practices with international regulators and proposed a unique protocol for cultivated meat within Brazil's existing novel foods framework. We expect Brazil to undertake a regulatory impact analysis in 2022. According to ANVISA, Brazil plans to adopt a model similar to that of the United States and European Union. At a high level, companies will first submit an application including information about their product to the regulator early in the R&D process. The regulator will then analyze the product's safety, likely under the current novel foods regulatory framework.



Israel

In 2020, Israeli prime minister Benjamin Netanyahu became the **first head of government to try a cultivated meat product**. In 2021, Israeli president Isaac Herzog became **the first president in the world to taste cultivated meat**. The president sampled cultivated chicken from Israeli company Future Meat at a reception for Israel's COP26 delegation, which included GFI Israel managing director Nir Goldstein.

In January 2021, an Israeli government forum aimed at strengthening the country's alternative protein industry conducted its first roundtable, led by the prime minister's office. After the roundtable, the Ministry of Health announced that a team of experts would study cultivated meat technologies and assess their safety. This research will equip the National Food Control Service—the department within the Ministry of Health that oversees food production—to evaluate future applications for regulatory approval to produce and market cultivated meat products in Israel.



President Isaac Herzog and his wife, Michal Herzog, sampling Future Meat's cultivated chicken. Image credit: Amos Ben Gershom

The Israeli government also continues to push the envelope with public investment in the cultivated meat sector. In October 2021, the Israel Innovation Authority announced a ₪220 million (\$69 million) investment in four new innovative consortia, including a cultivated meat consortium composed of companies and research institutions. The cultivated meat consortium will be led by Israel's largest meat company, Tnuva.



Japan

There is some indication that, based on interpretation of Japanese law, it could already be permissible to sell cultivated meat in Japan, so long as cultivated meat products and production processes do not externally source growth factors or use immortalized cells. But if it wants a robust cultivated meat market, Japan must establish a clear regulatory framework and a safe and standardized research and commercialization oversight process.

Although Japanese regulators have yet to act, a think tank called the Japanese Center for Rule-Making Strategy has put together the Cellular Agriculture Study Group, a consortium of industry members, academics, and other experts that makes policy recommendations to the government. The think tank also leads the Japan Association for Cellular Agriculture, a public-private partnership that works to develop rules for cell-based food products.

International standard-setting organization to address alternative proteins

In February 2021, GFI was granted official observer status in the Codex Alimentarius (“Food Code”) Commission, an international body with 188 member countries and the European Union that sets forth voluntary global standards and guidelines for food safety, trade, and regulation in a publication called the *Codex Alimentarius*. Run jointly by the UN Food and Agriculture Organization (FAO) and the World Health Organization (WHO), the Codex Alimentarius Commission significantly influences food policy in many member countries and often forms the basis for national legislation.

To build knowledge of and support for alternative proteins within Codex, and more broadly across the WHO and FAO, GFI’s U.S. and international team members have developed workshops and presented to a number of teams at these institutions. Notably, last spring WHO Western Pacific Region and GFI joined forces with GFI’s global affiliates to host a historic two-day workshop—Regulatory and Food Safety Aspects of Alternative Proteins for Conventional Animal Products. More than 120 people attended, including the chairman of Codex and several senior officials from the FAO and WHO. The **in-depth technical, regulatory, and industry insights** provided by GFI’s team and academic partners raised the profile of alternative proteins with key decision-makers at the WHO, FAO, and Codex.

As alternative protein offerings grow worldwide, the FAO and WHO have encouraged Codex to prepare to address overarching and emerging issues relating to alternative proteins and other novel foods in a timely manner. GFI believes Codex guidance on alternative proteins should be as straightforward, fair, and efficient as possible. To this end, GFI made a **formal written submission** to Codex advocating a transparent process to consider issues related to alternative proteins and inviting the FAO and WHO to call on GFI as a resource and a liaison to companies and scientists in the alternative protein industry. Jessica Almy, vice president of policy, also presented GFI’s position at the commission’s 44th meeting in November 2021.

Early 2022 update: In March 2022, the Codex Secretariat issued a circular letter seeking comment from member countries and observers on developments related to alternative proteins. A subcommittee will also prepare a report assessing the applicability of various Codex tools that could be used to guide the organization’s work on novel foods, including alternative proteins. GFI is excited to work with Codex to advance regulatory guidance that will help ensure a more sustainable, secure, and just global food system.



Singapore

In November 2020, the Singapore Food Agency (SFA) became the first national regulator to **green-light the sale of a cultivated meat product**, approving Eat Just's cultivated chicken for use as an ingredient in the company's chicken bites. Although this regulatory approval was a landmark achievement for the global cultivated meat industry, it was limited to Eat Just's specific product and manufacturing process. SFA, however, approved additional cultivated meat products in 2021. GOOD Meat, a division of Eat Just, earned regulatory approval for several new types of cultivated chicken products, including cultivated chicken breast.

In another positive development, in July 2021, SFA granted scientific manufacturing firm Esco Aster a license to manufacture cultivated meat products from cells that have gone through the regulator's safety assessment review. This will give cultivated meat companies the option to produce their products in a facility that has already received the green light from regulators. For now, companies looking to sell cultivated meat in Singapore must still seek authorization from SFA for their specific products, but the latest round of approvals is a sign that the country plans to be a hub for the industry.

SFA has not indicated whether it plans to issue a comprehensive regulatory framework or continue approving cultivated meat products on a case-by-case basis. In December 2021, SFA updated a **guidance document** on novel food safety assessments, which outlines the information that cultivated meat companies must submit when seeking approval of their products. However, the guidance does not detail the standards manufacturers will need to satisfy to obtain approval. SFA strongly encourages companies interested in selling cultivated meat products in Singapore to contact the regulatory body early in the R&D and commercialization planning process.



China

The Chinese government has historically invested in emerging technologies, including solar panels, lithium-ion batteries, and electric vehicles. With alternative proteins on the rise, China is turning its attention to the innovative cultivated meat industry.

In late 2020, China's Ministry of Science and Technology launched a ¥600 million (\$93 million) R&D program called "Green Biological Manufacturing" that supports projects in a number of sectors, including plant-based and cultivated meat manufacturing. An estimated ¥20 million of the funding is used to develop alternative proteins.

In June 2021, the Chinese government announced a three-year project called "High-Efficiency Biological Manufacturing Technology of Artificial Meat." Jiangnan University, which has one of mainland China's top agricultural science programs, will lead the project.

The National Natural Science Foundation of China has also provided funding for cultivated meat research teams.

In December 2021, China's Ministry of Agriculture and Rural Affairs released a highly anticipated five-year plan designed to accomplish long-term national goals set by the country's top political leaders. The plan provides a blueprint for strengthening innovation in "frontier and cross-disciplinary technologies," including the manufacturing of cultivated meat and other "future foods."

As Mirte Gosker, acting managing director of GFI Asia Pacific said to **TIME Magazine**, "As the world grapples with the twin challenges of skyrocketing protein demand and diminishing natural resources, a rapid shift towards plant-based and cultivated meat is a critical element of how we increase food security, mitigate environmental degradation, and alleviate global poverty. By including game-changing food technologies like cultivated meat, [China's] national leaders are saying publicly what others around the world have long hoped: that China intends to go all-in on building the future of food."

Despite these plans and investments, China has not yet announced how it will regulate or oversee the manufacturing and sale of cultivated meat.



United States

Federal regulation

Although the United States has yet to issue regulatory guidance specific to cultivated meat and seafood, 2021 was a big year in the march toward regulatory approval. Now the question is, When will the first cultivated meat product come to market with the blessing of regulators? Below we outline several milestones in the country's development of a comprehensive regulatory framework.

- March 2021 was the final deadline to submit comments to FDA in response to a **request for information** relating to cultivated seafood labeling that the agency published in 2020. The agency will use information obtained through the comment process to determine what action, if any, it should take to ensure that cultivated fish and shellfish are labeled properly. **GFI submitted a comment** urging FDA to adopt a clear and sensible approach that allows cultivated seafood companies to use terms familiar to consumers, avoids prematurely mandating specific terminology, and is based on evidence of consumer understanding.
- In September 2021, USDA issued an **advance notice of proposed rulemaking** on the labeling of cultivated meat and poultry products. Like FDA, USDA sought public comment and will use the information collected to determine what rules or guidance, if any, are required to ensure cultivated meat and poultry is labeled appropriately. **GFI's comment** encourages USDA to adopt a practical and flexible regulatory framework that permits cultivated meat companies to use familiar terms, avoids rigid and premature regulation of terminology, and ensures a fair playing field for cultivated meat and poultry.
- Although USDA has yet to issue regulatory guidance for labeling cultivated meat and poultry, the agency set forth a **process for label preapproval** in its advance notice of proposed rulemaking. Cultivated meat and poultry companies seeking to retail their products before USDA completes its rulemaking process can submit their labels to USDA's Food Safety and Inspection Service for review.
- FDA also encourages companies planning to produce cultivated meat, poultry, or seafood products in the United States to contact the agency's Center for Food Safety and Applied Nutrition early and often to discuss safety approvals.

Federal funding

The U.S. government began to step up public funding for cultivated meat in 2021. In addition to USDA granting \$10 million to create a center for excellence in cellular agriculture at Tufts University, the National Institutes of Health granted \$1.5 million to Defined Bioscience to develop a cell culture medium supplement.

In addition, a growing number of lawmakers are calling for increased federal support. Chair of the House Appropriations Committee Rosa DeLauro has identified alternative proteins, including cultivated meat, as a climate solution and championed government investment in protein innovation. Likewise, 15 House members and three senators called on John Kerry, in his role as presidential envoy for climate, to include alternative proteins as a key tool for mitigating the climate crisis. In August, House Rules Committee chair Jim McGovern, House Education Committee chair Julia Brownley, and 44 other members of Congress called on the House Agriculture Committee to fund alternative protein research as part of the budget reconciliation bill. And in December 2021, Rep. Ro Khanna and 10 other members of Congress sent a letter to Secretary of Agriculture Tom Vilsack urging USDA to include alternative protein research funding in the agency's FY 2023 budget request.

State litigation

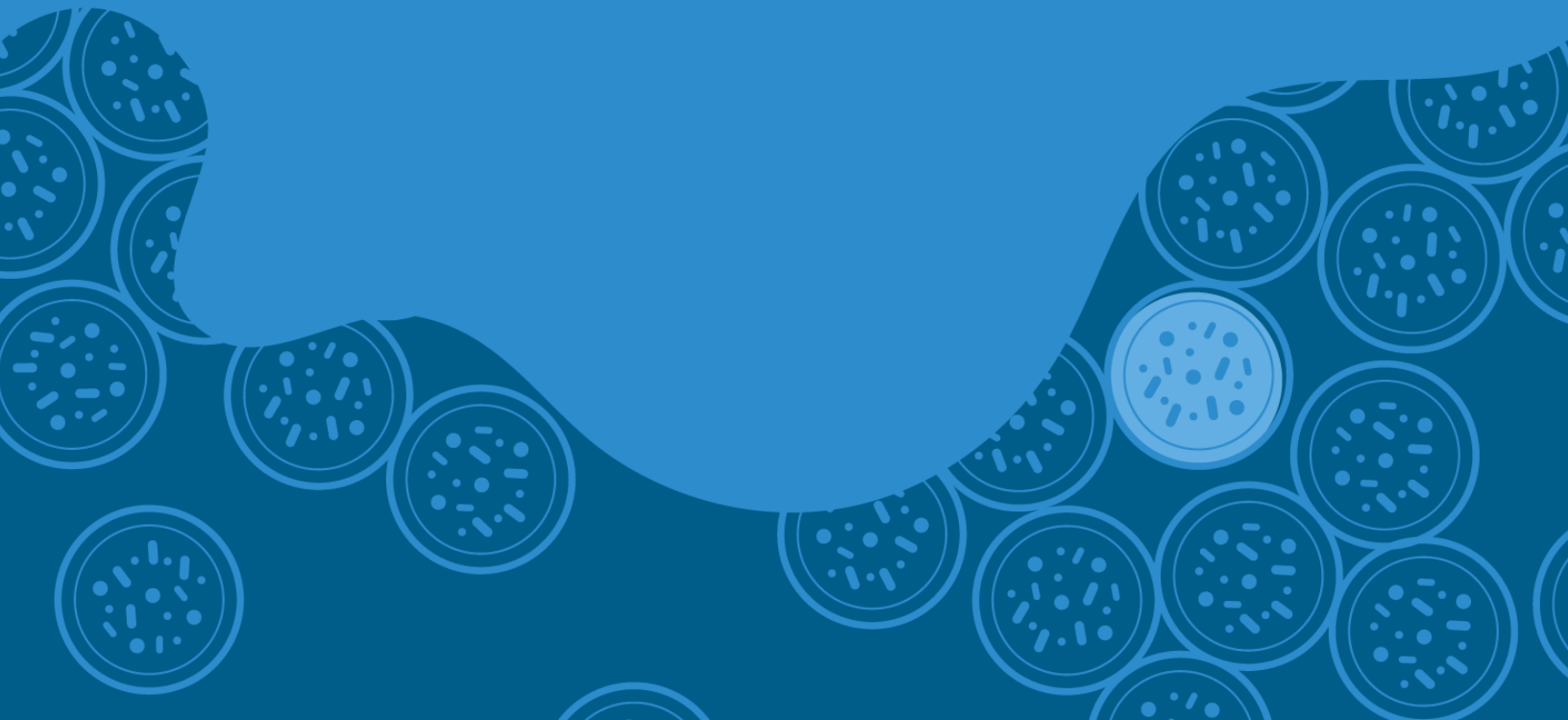
A handful of states have enacted “label censorship” laws that restrict cultivated meat from being labeled as “meat.” The laws ban terms such as “burger,” “sausage,” and “chicken” on products that are not harvested from an animal carcass. GFI and other groups have challenged these laws in court on the grounds that they violate the First Amendment and other constitutional provisions, which helps clear the way for accurate labeling of cultivated meat. No new label censorship bills were passed in 2021, but litigation against existing laws continued in several states.

- In **Louisiana**, GFI and co-counsel the Animal Legal Defense Fund (ALDF) brought suit on behalf of Turtle Island Foods (d/b/a Tofurky), arguing that the state’s label censorship law violates First Amendment free speech principles and the Fourteenth Amendment right to due process. In March 2022, the court granted Tofurky’s motion for summary judgment and enjoined Louisiana from enforcing the law, concluding that it “impermissibly restricts commercial speech.”
- In **Oklahoma**, ALDF brought a new challenge to the state’s label censorship law on behalf of plaintiffs Tofurky and the Plant Based Foods Association after a judge had denied a motion to prevent enforcement of the law. The new complaint argues that Oklahoma’s law is vague, overly burdensome, and preempted by federal law. At the time of this report, the case remains pending in federal court.
- In **Arkansas**, a federal district court judge granted Tofurky a preliminary injunction, preventing the state from enforcing its label censorship law against the company on the grounds that the law likely violates constitutional free-speech protections. Tofurky has since asked the court to enjoin the state from enforcing the law against anyone, arguing that the law is invalid on its face. The court has yet to rule on that motion.
- In **Missouri**, a federal district court declined to grant Tofurky and GFI a preliminary injunction 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 the ruling, agreeing with the lower court’s determination that the law does not apply to Tofurky’s labels.

Are we missing something? Did we get something wrong? We’d appreciate your feedback via [this form](#).

Section 5

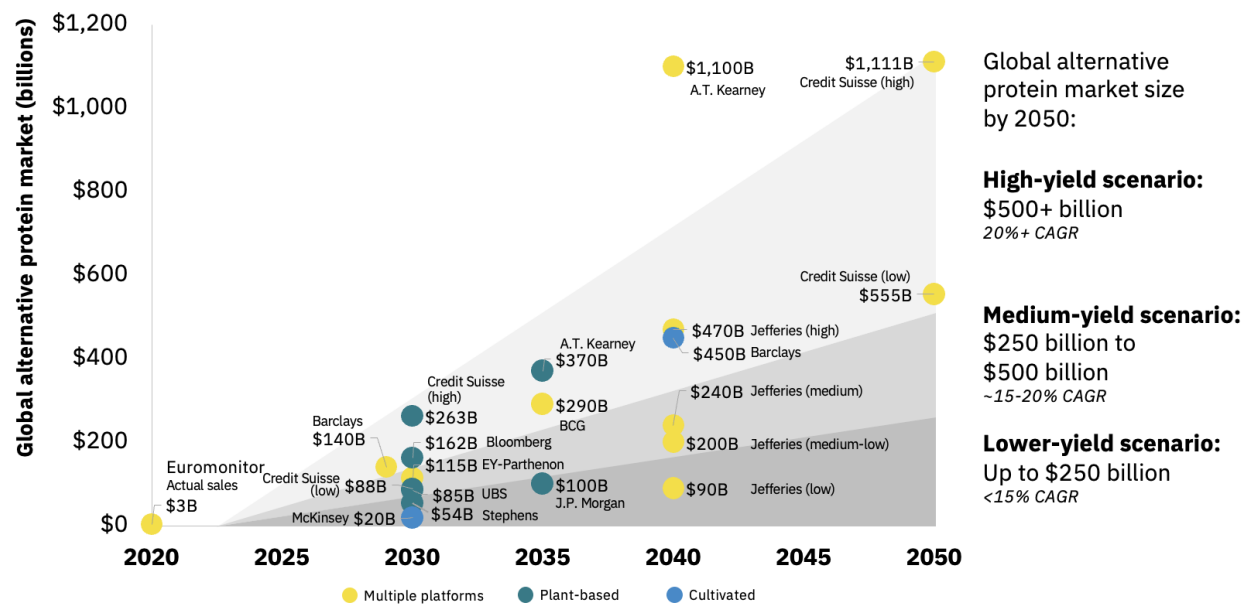
Conclusion and forecast



Section 5: Conclusion and forecast

Capturing even a fraction of the global meat market—estimated in 2020 at **328 million tons** and worth more than \$1 trillion—is a colossal opportunity. Doing so will require a remarkable deployment of scientific innovation, infrastructure development, investment, and—crucially—a robust ecosystem to support the industry’s growth. Fortunately, 2021 was a year of growth and commercialization for the field of cultivated meat. The industry made considerable progress in scaling the technology, desiloing the industry via commercial partnerships, and carving out a key regulatory precedent. But there is a lot more work to do, and GFI’s teams of scientists, lobbyists, lawyers, and corporate engagement specialists all over the world are focused on projects that will lift up the entire cultivated meat sector globally, allowing us to sustainably meet the world’s growing demand for protein.

Figure 15: Projections of market size



Source: GFI synthesis of multiple reports

We expect the alternative protein industry to grow meaningfully over the coming decades. And this view is supported by numerous research organizations, investment firms, and consultants that have published forecasts of the industry’s growth, many of which are mapped in the chart above.

Forecasts range from lower-growth scenarios of up to \$250 billion in annual sales to high-growth scenarios of \$500+ billion in annual sales of alternative proteins by 2050. A couple of key factors could account for the wide range of these estimates:

- The inherent uncertainty of making predictions early in an industry’s life cycle.

- The path-dependency of industry growth based on a range of drivers across the areas of scientific and technological innovation, commercial and consumer trends, and regulatory and government action.

Factors that would drive sales growth include the following:

- **Supportive government and regulatory action.** Governments have incredible power to help the industry grow exponentially by investing in open access R&D, supporting the private sector, and creating a clear regulatory path to market for cultivated meat.
- **Investment and innovation** that allow scaled production of a wider variety of products that are both organoleptically equivalent to conventional animal products and competitively priced.
- **Product development** to produce key formats like whole muscle cuts and hybrid products that combine cultivated, fermentation-derived, and plant-based ingredients to enhance sensory and functional attributes.
- **Scientific advancement** in areas of cell culture media, scaffolding, cell lines, and bioreactors and bioprocessing technologies.
- **Scaled production capacity** that achieves greater economies of scale and a resilient supply of alternative proteins.
- **Greater consumer adoption** that builds on existing momentum to shift to alternative proteins, driven by a variety of motivators, such as public health risks, animal welfare, and environmental impacts like climate change.

Other factors would nudge alternative proteins onto a slower growth path:

- A lack of public and private investment in innovation and production.
- Persistent technical challenges.
- Climate change risks stymieing ingredient availability or commercial viability.
- A lack of clear regulation impeding innovation.
- Government censorship of labels or other roadblocks to the technological or consumer progress of alternative proteins.

For cultivated meat specifically, **McKinsey & Company** estimates that the market may reach \$2 billion in annual sales in just a few years and up to \$20 billion or even \$25 billion in sales by 2030 if cultivated meat companies are able to “replicate a wide variety of both processed meats and whole cuts” and distribute them globally. In McKinsey’s view, the \$5 billion bump that would take annual sales from \$20 billion to \$25 billion is largely driven by companies’ ability to sell into “multiple large meat-consuming countries and regions (e.g., China, US, EU, Brazil, India),” rather than being limited to North America, Europe, and select Asia-Pacific countries.

Summary: Projections for cultivated meat market size

McKinsey & Company

- Base case: \$20 billion in sales by 2030.
- High-growth scenario: \$25 billion in sales by 2030.
- The extra \$5 billion per year would be driven by companies' ability to sell into key regions and countries, such as China, the United States, the European Union, Brazil, and India.

Barclays

- Base case: \$450 billion in annual sales by 2040.
- Market share of 20% by 2040, increasing to 40% by 2050.

EY

- Market share of 3% by 2030, increasing to 22% by 2040.

Meanwhile, in Barclays' recently published paper "Cultured Meat: From Lab to Fork," the bank forecasts a base case of \$450 billion in annual sales of cultivated meat by 2040, with cultivated meat accounting for 20 percent of the meat market that year and increasing to a 40 percent market share by 2050. While recognizing that the segment has "no relevant market share" today, Barclays expects that "adoption will be faster than for other food alternatives, given the similarity of cultivated and traditional meat and its ability to address several challenges faced by the animal-based meat industry," as well as consumers' growing concerns for sustainability and animal welfare.

In an **October 2021 analysis**, EY said that cultivated meat could reach cost and sensory parity by the end of the decade. EY forecasts that by 2030 cultivated meat may reach a meat market share of 3 percent, growing to 22 percent by 2040. Additionally, EY noted that cultivated fats might reach parity sooner and be incorporated into plant-based products in the coming years.

While the industry's precise growth path will remain uncertain for some time, industry stakeholders—startups and established food companies, consumers, investors, and global governments—are already charting that path and pointing it in the direction of a more sustainable and secure food future.

Expert predictions

We asked industry experts for their predictions on what's next in cultivated meat.



In the long term, although it is still too early to predict percentages, JBS believes that cultivated protein will occupy a relevant space in the food supply. Our new production plant in Spain, for example, is expected to reach commercial production in mid-2024. In the short term, the industry will work hard to improve technology, gain scale and reduce costs, in order to facilitate access to a greater part of the global population.

—Eduardo Noronha, Global Head of HR and Operational Excellence at JBS



The rise of companies that make innovations available to all cultivated meat producers will accelerate the progress in the sector. I expect to see many major collaborations across input players to make technologies compatible with each other.

—Ernst Van Orsouw, CEO at Roslin Tech



We think more and more start-ups will continue to grow in the cultivated meats and seafood area, and also in the supporting industries like growth/nutrient media, scaffolds and bioreactors. In terms of products and collaboration, we expect to see more hybrid blend products with plant-based and cultivated meats or seafood which is a great avenue to widen the choices available to consumers.

—Ka Yi Ling, co-founder and CTO at Shiok Meats



Public companies have been keen to gain exposure to cultivated meat, a trend we anticipate will accelerate given the broad range of B2B/B2C private companies and recent pure-play IPOs. Investors have been encouraged by the pace with which the industry has achieved key manufacturing milestones in recent months, and they have a growing interest in how products will be regulated and produced at commercial scale. Potential US regulatory approval in 2022 would likely act as an additional catalyst for investors, as well as for other countries hoping to leverage the associated regulatory blueprint.

—Hiral Patel, head of sustainable and thematic investing in equity research at Barclays



Cultivated meat was once thought of as science-fiction. Today, it's on the path towards commercialization in the US. As the industry advances its focus on consumers, we expect to see greater awareness around cultivated meat, poultry and seafood in 2022. Shifts in conversation can already be seen with questions pivoting from “what is cultivated meat?” to “what does cultivated meat taste like?” This will soon evolve further into “where can we eat cultivated meat?”

—Amy Chen, COO at UPSIDE Foods



“We are seeing the folks who developed pilot or small demonstration scales in 2021 and the first half of 2022 move directly into meaningful production and starting to push to current accepted limits on scale in 2022 and 2023. I expect that four to ten companies will be delivering first products at volume and scale by the end of 2022, serving customers consistently in restaurant settings in the United States and globally. The number of folks producing at pilot scale will likely quadruple in 2022.”

—**John Ellersick, president at Next Rung Technology**



“In order for the community around cultured meat to benefit from the momentum created predominantly by the huge potential of cultivated meat being more resource efficient and environmentally friendly, we need an increased focus on knowledge sharing. As academics we enjoy collaborating with industries but it is also critical that we publish our scientific findings in order to contribute to the overall development of this emerging field. This is where public funding is pivotal and where the societal responsibility across countries can assist the green transition in other ways than the exclusive focus on plant-derived solutions.”

—**Dr. Jette Young, Associate Professor, Aarhus University**

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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 www.gfi.org.



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