PitchBook

PitchBook Data, Inc.

John Gabbert Founder, CEO

Nizar Tarhuni Vice President, Institutional Research and Editorial

Paul Condra Head of Emerging Technology Research

Institutional Research Group

Analysis

Alex Frederick
Senior Analyst, Emerging Technology
alex.frederick@pitchbook.com

Data

Matthew Nacionales
Data Analyst

pbinstitutionalresearch@pitchbook.com

Publishing

Designed by **Megan Woodard**

Published on April 28, 2023

Contents

EMERGING TECH RESEARCH

Applications for Synthetic Biology in Agriculture

PitchBook is a Morningstar company providing the most comprehensive, most accurate, and hard-to-find data for professionals doing business in the private markets.

Executive summary

As global challenges such as population growth, climate change, and resource scarcity continue to mount, the agriculture sector faces increasing pressure to adapt and innovate to meet the growing demand for food sustainability and efficiency. Synthetic biology (synbio), a cutting-edge interdisciplinary field that combines biology, chemistry, engineering, and computer science, offers promising solutions to these challenges, with the potential to revolutionize agriculture and reshape the future of global food production. This note provides a comprehensive analysis of the applications of synthetic biology in agriculture, examining the market and venture landscape, emerging technologies, and the key players driving progress in this rapidly evolving sector.

We find that synbio has significant potential to revolutionize agriculture by enabling the development of new plant varietals and nutrients, among other applications. Synbio can also help address critical challenges facing the agriculture industry, such as reducing greenhouse gas emissions, increasing crop yields, and enhancing food safety. However, the technology is still in its early stages of development, and several regulatory and ethical concerns need to be addressed before its full potential can be realized. Additionally, public agtech synbio companies have faced revenue and stock performance difficulties, mainly due to obstacles in managing cash flow and attaining product-market fit. Several prominent companies such as Novozymes, GreenLight Biosciences, and Calyxt have recently disclosed M&A transactions or proposals.

Overview

Synbio is an interdisciplinary field that combines biology, engineering, and computer science to design and construct new biological systems or modify existing ones. In agriculture, synbio is increasingly being used to develop innovative solutions to some of the industry's most pressing challenges, including food security, environmental sustainability, and climate change. These solutions can improve crop yields, enhance nutrient uptake, reduce the need for pesticides and herbicides, and develop new plant varieties with desirable traits. Synbio in agriculture can also create sustainable and environmentally friendly agricultural practices. Key applications for synbio in agriculture include:

- **Crop improvement:** Synbio can improve crop yields by modifying the genetic code of plants to increase their resistance to pests and diseases, improve their nutrient uptake, or even provide early warning signs of distress. For example, Inari Agriculture is developing crop varieties using CRISPR gene-editing technology to make precise modifications to plant genomes, such as bolstering drought resistance.

- **Precision agriculture:** Synbio can be used to create sensors and other technologies to monitor crop growth and detect problems early. For example, Innerplant is using genetic engineering to develop crop "data traits" that can signal stress weeks prior to typical visual indicators, enabling timely and precise intervention.

- **Soil health:** Synbio is increasingly used to improve soil health by enhancing the soil microbiome and reducing reliance on synthetic fertilizers. For example, Sound Agriculture uses microbe engineering to develop soil amendments that trigger soil microbes to fix atmospheric nitrogen and release phosphorus, converting these elements into plant-available nutrients. The result is healthier crops, enhanced yields, and reduced reliance on synthetic fertilizers.

- **Animal health:** Synbio is being used to improve animal health in the form of probiotics and vaccines, gene engineering for healthier animal traits, and developing new treatments for animal diseases. For example, Acceligen uses gene-editing techniques—such as CRISPR-Cas9—to create unique genetic traits in livestock animals, like cattle that are resistant to bovine respiratory disease.

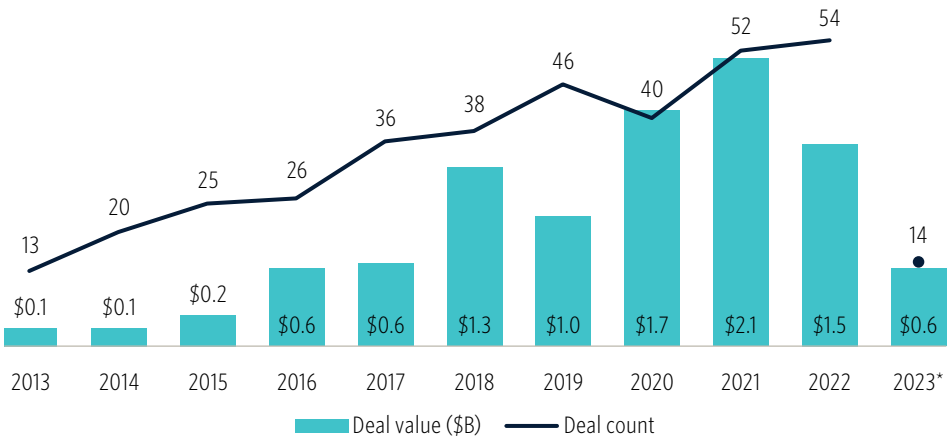
- **Bioremediation:** Synbio can be used to clean up contaminated soils and waterways. For example, Allonnia is a company that uses synbio to create microbes that can break down pollutants in the soil, reducing the environmental impact of agricultural practices.

VC activity

VC funding of companies developing synbio solutions for agtech has risen steadily over the past decade. In 2022, we logged $1.5 billion invested across 54 deals. Deal values regressed 29.4% YoY, while deal counts increased by 3.8%. This pattern mirrors the funding trajectory of agriculture technology (agtech), which saw funding declines in light of market volatility. Notable deals in 2022 include the $200.0 million Series I in DNA Nexus and the $200.0 million Series E in Synthego.

The first quarter of 2023 closed with promising deal activity. Companies in this space captured $571.7 million across 14 deals, pacing to surpass the record $2.1 billion invested in 2021. This quarter's top deals include Asimov's $175.0 million Series B and Colossal Laboratories & Biosciences' $150.0 million Series B.

Agtech synbio VC deal activity



Source: PitchBook • Geography: Global
*As of March 31, 2023

Key VC-backed companies by VC raised to date*

Company	Segment	VC ($M) raised to date	Post-money valuation ($M)	Most recent VC deal type
Indigo Agriculture	Microbe engineering	$1,701.6	$3,950.0	Series H
Pivot Bio	Microbe engineering, DNA synthesis	$616.7	$1,700.0	Series D
Inscripta	Genome editing	$487.3	N/A	Late-stage VC
Inari	Genome editing	$476.0	$1,500.0	Series E
Synthego	Genome editing	$459.5	$1,200.0	Series E
DNAnexus	DNA synthesis	$436.7	$620.0	Series I
DNA Script	DNA synthesis	$294.0	$659.7	Series C
AgBiome	Genome editing, microbe engineering	$236.2	N/A	Series D
Colossal Laboratories & Biosciences	Genome editing	$230.0	$1,450.0	Series B
Lygos	Metabolic engineering	$209.6	N/A	Late-stage VC

Source: PitchBook • Geography: Global
*As of March 31, 2023

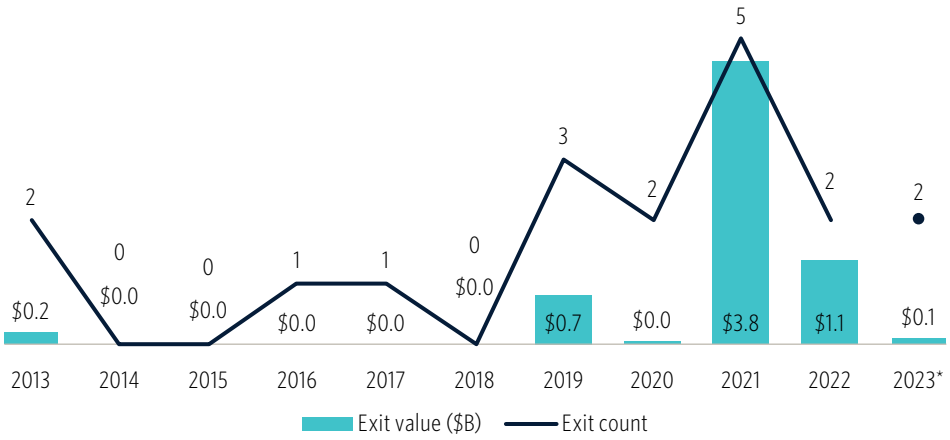
Top VC investors since 2018 by deal count*

Investor	Deal count	Angel and seed	Early-stage VC	Late-stage VC	Venture growth	Investor type
Alexandria Venture Investments	10	1	1	7	1	CVC
Fall Line Capital	9	0	1	6	2	VC
Syngenta Group Ventures	9	1	0	4	4	CVC
S2G Ventures	9	0	0	7	2	VC
Cavallo Ventures	9	1	1	4	3	CVC
Leaps by Bayer	9	0	3	5	1	CVC
iSelect Fund	8	1	0	5	2	VC
DCVC	7	1	1	4	1	VC
Sofinnova Partners	7	0	1	6	0	VC
Aliment Capital	7	0	3	4	0	VC

Source: PitchBook • Geography: Global
*As of March 31, 2023

Agtech synbio companies recorded healthy exit activity relative to other agtech segments. We logged $1.1 billion exited across two exits in 2022 and $3.8 billion exited across five exits in 2021. Two exits in Q1 2023 are on par with expectations, given the challenging exit environment. We logged an aggregate exit value of $69.5 million. Notable exits include Benson Hill's reverse merger for $403.0 million in 2021, Caribou Biosciences' IPO for $304.0 million in 2021, and the 2022 acquisition of BioPhero by FMC for $190.7 million. We expect exit activity to remain stunted in the near term until market volatility recedes.

Agtech synbio VC exit activity



Source: PitchBook • Geography: Global
*As of March 31, 2023

Key VC exits by size*

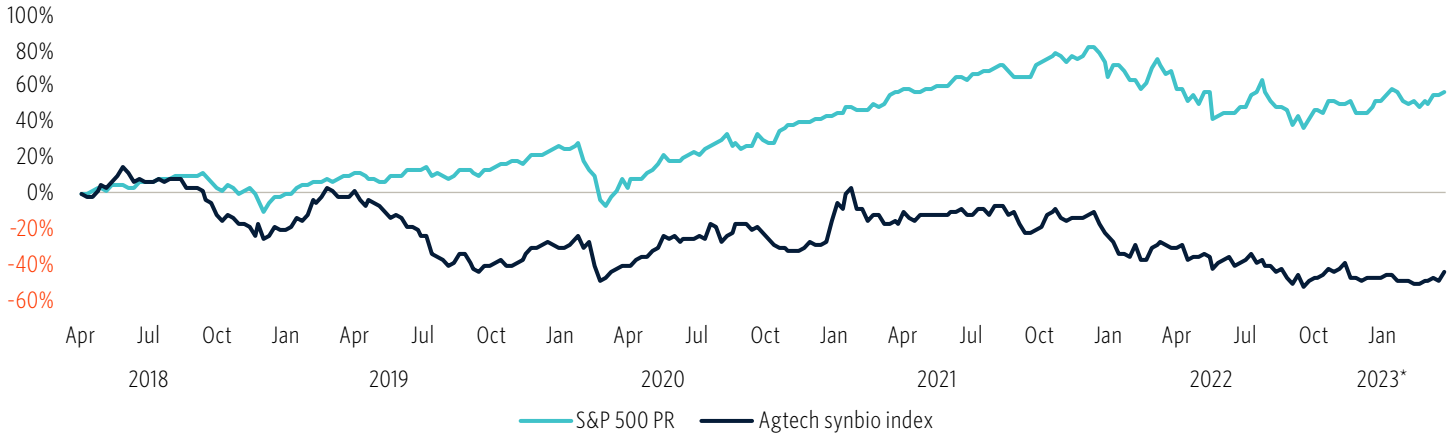
Company	Close date	Technology	Exit size ($M)	Exit type	Acquirer(s)/Index
Zymergen	April 22, 2021	Microbe engineering	$2,536.1	Public listing	Nasdaq
GreenLight Biosciences	February 4, 2022	Genome editing, RNA engineering, cell-free	$927.0	Public listing	Environmental Impact Acquisition
Precision BioSciences	March 28, 2019	Genome editing	$658.1	Public listing	Nasdaq
Benson Hill	September 30, 2021	Genome editing	$609.0	Public listing	Star Peak Corp II
Caribou Biosciences	July 23, 2021	Genome editing	$603.3	Public listing	Nasdaq
BioPhero	July 19, 2022	Protein engineering	$190.7	Acquisition	FMC
One Codex	February 1, 2021	Microbe engineering	$83.4	Acquisition	Invitae
Agrivida	January 10, 2023	Protein engineering	$69.5	Acquisition	Novus International, Presidio Ventures
Terragen Biotech	December 11, 2019	Microbe engineering	$18.2	Public listing	Australian Securities Exchange Limited
enEvolv	March 19, 2020	Genome editing	$10.7	Acquisition	Zymergen

Source: PitchBook • Geography: Global
*As of March 31, 2023

Market analysis

Collectively, public agtech synbio companies have experienced lackluster revenue and stock performance. Although a few companies have seen strong growth, revenues have been choppy. As an index, synbio agtech companies have significantly underperformed the S&P 500 over the past five years. Providers have largely struggled to find product market fit and have operated at a loss. Cashflow challenges appear to be leading companies to consider M&A opportunities. A number of key companies recently announced consideration or acceptance of M&A offers.

Agtech synbio stock price history



Source: PitchBook • Geography: Global
*As of April 25, 2023
Note: Companies in index include Benson Hill, Bioceres Crop Solutions, Calyxt, Caribou Biosciences, Evogene, GreenLight Biosciences, Novozymes, Precision BioSciences, Terragen Biotech, and Yield10 Bioscience.

Novozymes is the strongest performer of the agtech synbio cohort with annual revenues of $2.1 billion in 2020 and growing toward an estimated $3.0 billion in 2025. Despite the comparatively strong performance, in December 2022, Novozymes announced a planned merger with incumbent bioscience company Chr. Hansen. Both companies operate in agriculture, as well as food ingredients, and this merger may be in response to the merger of Koninklijke DSM and Firmenich in May 2022.

GreenLight is focused on developing human vaccines and therapies, as well as agricultural solutions. The company went public via SPAC in early 2022. The company initially rode the wave of enthusiasm for messenger RNA (mRNA) vaccines during the COVID-19 pandemic but has struggled to bring products to market, leading to cashflow challenges. In March 2023, the company announced that it was entertaining a buyout offer from Fall Line Capital.

Gene editing company Calyxt spun out of biopharma company Cellectis and went public in 2017 with plans to develop seed-traits for traditional agriculture through gene editing. The company has since largely pivoted to new models, including licensing its technology and producing plant-based compounds. The company has operated at a loss since it went public and was nearly delisted by Nasdaq after falling out of compliance. It recently announced plans to merge with rival Cibus.

Agtech synbio actual and forecast revenue*

Company	Ticker	Enterprise value ($M)	Actual revenue ($M)			Forecast revenue ($M)			YoY revenue growth				
			20A	21A	22A	23E	24E	25E	21A	22A	23E	24E	25E
Benson Hill	BHIL	$264.2	$59.1	$90.9	$381.2	$397.5	$405.4	$409.1	54%	319%	4%	2%	1%
Bioceres Crop Solutions	BIOX	$898.5	$172.4	$206.7	$328.5	$434.0	$522.0	$642.9	20%	59%	32%	20%	23%
Calyxt	CLXT	$183.7	$23.9	$26.0	$0.2	$2.5	N/A	N/A	9%	-99%	1,492%	N/A	N/A
Caribou Biosciences	CRBU	$52.3	$12.4	$9.6	$13.9	$16.0	$20.0	$24.0	-22%	44%	16%	25%	20%
Evogene	EVGN	$8.5	N/A	$7.6	$5.7	$13.6	$25.7	N/A	N/A	-25%	138%	89%	N/A
GreenLight Biosciences	GRNA	$66.3	$1.0	$0.0	$6.4	$2.1	$17.6	N/A	-100%	N/A	-67%	739%	N/A
Novozymes	NZYM B	$15,006.1	$2,142.1	$2,377.3	$2,480.9	$2,680.8	$2,812.3	$2,958.3	11%	4%	8%	5%	5%
Precision BioSciences	DTIL	-$64.0	$24.3	$115.5	$25.1	$23.1	$26.6	$70.5	376%	-78%	-8%	15%	165%
Terragen Biotech	TGH	$1.5	$665.3	$853.4	$913.6	$813.7	$827.0	$917.7	28%	7%	-11%	2%	11%
Yield10 Bioscience	YTEN	$13.2	$0.8	$0.6	$0.5	$0.3	$2.4	$9.3	-23%	-27%	-37%	742%	287%
Median			**$24.3**	**$58.5**	**$19.5**	**$19.6**	**$26.6**	**$409.1**	**141%**	**-67%**	**0%**	**36%**	**1,436%**
Average			**$344.6**	**$368.8**	**$415.6**	**$438.4**	**$517.7**	**$718.8**	**7%**	**13%**	**5%**	**18%**	**39%**

Source: PitchBook • Geography: Global
*As of April 25, 2023

Select exits

Several synthetic biology companies with exposure to agtech have experienced successful exits due to their innovative technologies, strategic partnerships, and the growing demand for sustainable agricultural solutions. Some of the most successful companies in this space include:

- **Benson Hill:** A plant genomics company that uses synthetic biology, data analytics, and cloud computing to enhance crop productivity and sustainability. The company's success can be attributed to its CropOS platform—a powerful computational tool that combines big data, artificial intelligence, and synthetic biology to accelerate crop improvement. CropOS enables the development of crops with improved yield, nutritional content, and resilience to environmental stressors. Benson Hill's innovative approach to plant genomics and its strategic partnerships with leading agricultural companies have positioned it as a key player in the agtech sector.

- **GreenLight Biosciences:** A biotechnology company focused on developing RNA-based solutions for agriculture and human health. In the agricultural space, GreenLight uses its proprietary cell-free bioprocessing platform to produce RNA molecules that can protect plants from pests and diseases, reducing the need for chemical pesticides. The company's success in agtech can be attributed to its innovative RNA-based approach, which offers a more targeted and environmentally friendly alternative to traditional chemical pesticides. GreenLight's technology has the potential to address key challenges in sustainable agriculture, such as pest resistance and environmental impact, making it a promising player in the agtech sector.

- **Caribou Biosciences:** A biotechnology company specializing in CRISPR-based gene-editing and gene regulation technologies. Although the company primarily focuses on healthcare applications, it has significant exposure to agriculture through strategic partnerships and the development of crop improvement technologies. Caribou's success can be attributed to its cutting-edge CRISPR-Cas9 technology, which allows for precise and efficient gene editing in plants. The company has also formed strategic partnerships with agricultural companies to apply its gene-editing technology to develop crops with improved yield, stress tolerance, and resistance to pests and diseases. The growing demand for sustainable and innovative agricultural solutions has contributed to Caribou's success in agtech.

These companies have been successful in the agtech space because they have leveraged synthetic biology and related technologies to create innovative solutions that address critical challenges facing agriculture, such as food security, resource scarcity, and climate change. Their success can also be attributed to their ability to form strategic partnerships with industry leaders and their commitment to advancing the sustainability and efficiency of global food production.

Industry partnerships

Several partnerships have been formed in the agriculture industry between synthetic biology startups and established incumbents to develop innovative solutions that address the challenges of food security, resource scarcity, and environmental sustainability. Here are some notable examples:

- **Ginkgo Bioworks and Bayer:** In 2018, Ginkgo Bioworks, a leading synthetic biology company, and Bayer, a global life sciences company, formed a joint venture called Joyn Bio. The partnership aimed to develop engineered microbes to help plants fix nitrogen from the atmosphere, reducing the need for synthetic nitrogen fertilizers. By combining Ginkgo's expertise in microbial engineering with Bayer's deep knowledge of agriculture, the partnership sought to develop sustainable solutions to increase crop productivity and reduce agriculture's environmental impact.[1]

- **Caribou Biosciences and DuPont Pioneer (now Corteva Agriscience):** In 2015, Caribou Biosciences, a CRISPR-based gene-editing company, and DuPont Pioneer, a major seed and agricultural products company, entered a strategic partnership to apply Caribou's CRISPR-Cas9 technology for crop improvement. The collaboration aimed to develop crops with increased yield, improved stress tolerance, and enhanced resistance to pests and diseases. The partnership brought together Caribou's expertise in gene editing with DuPont Pioneer's agricultural knowledge to advance the development of innovative agricultural products.[2]

- **Inari and InterGrain:** In February 2022, Inari, a seed technology company that leverages gene editing and synthetic biology, announced a strategic collaboration with InterGrain, an Australian cereal breeding company. The partnership aims to enhance the performance of wheat varieties in the Australian market by utilizing Inari's gene-editing technology platform to develop improved wheat seeds that can withstand environmental stressors such as drought, heat, frost, and disease. By combining Inari's expertise in gene editing and predictive design with InterGrain's knowledge of local growing conditions, the collaboration seeks to accelerate the development of more resilient and resource-efficient wheat varieties, leading to more sustainable and efficient food production in Australia.[3]

These partnerships demonstrate the potential of combining synthetic biology startups' innovative technologies with the resources and expertise of established agricultural companies. By working together, these companies can accelerate the development of sustainable and efficient solutions that address the critical challenges facing the agriculture industry.

1: "Bayer and Ginkgo Bioworks Unveil Joint Venture, Joyn Bio, and Establish Operations in Boston and West Sacramento," Cision PR Newswire, March 20, 2018.
2: "DuPont Predicts CRISPR Plants on Dinner Plates in Five Years," MIT Technology Review, Antonio Regalado, October 8, 2015.
3: "InterGrain and Inari Launch Collaboration to Deliver Step-Change in Wheat Yield Potential," Cision PR Newswire, February 22, 2022.

Agtech synbio market map

Genome engineering

INARI, INSCRIPTA, SYNTHEGO, ASIMOV, pairwise, Tropic, recombinetics, ScoutBio, CATALOG

Microbe engineering

indigo, AgBiome, CIBUS, NewLeaf symbiotics, loam, Terramera, native, andes, BioConsortia, BIOMEDIT

RNA engineering

VESTARON, PEBBLE LABS, RNAissance AG, 禾牧, Spindle Biotech, Yroot, SILVEC BIOLOGICS

Protein engineering

InfiniteEnzymes, Syocin, PROTEINEA

Biosensors

TRACE GENOMICS, phylagen, INNERPLANT, AgroSustain, Vivent, MENON, PES TECHNOLOGIES

Metabolic engineering

LYGOS, Sound, AFINGEN

DNA synthesis

DNAnexus, DNASCRIPT, ANSA, nuclera, MOLECULAR ASSEMBLIES, evonetix

Directed evolution

AMFORA, PIVOT BIO, JOYN BIO

Cell-free systems

strateos, EnginZyme, Debut, LenioBio, 猎境生物, allonnia, OriCiro

Market size

The market size for synbio companies with exposure to agriculture can vary depending on different factors, such as the specific subsector within agriculture, the geographic location, and the size of the targeted market. However, according to a report by Acumen Research and Consulting, the global market size for agricultural biotechnology was valued at $32.1 billion in 2022 and is projected to reach $77.4 billion by 2032, growing at a CAGR of 9.4% during the forecast period. The report includes companies involved in developing and commercializing genetically modified crops, biofuels, and other agricultural products based on synbio.[4] Another report by The Business Research Company estimates the global synbio market size to reach $39.1 billion by 2027, with the agriculture sector being one of the key end-users.[5] It's important to note that these estimates are subject to change and are affected by factors such as regulatory policies, technological advancements, and market competition.

Benefits and challenges

Synbio holds great promise for transforming agriculture by offering novel and sustainable solutions to pressing global challenges. By engineering plants with improved characteristics, such as enhanced yields, resilience to environmental stresses, and enriched nutritional content, synbio can contribute significantly to global food security and environmental sustainability. However, the application of synbio in agriculture also raises ethical, social, and regulatory concerns, including potential impacts on biodiversity, public perception, and intellectual property rights. Consequently, it is essential to carefully balance the benefits and challenges of synbio in agriculture to ensure responsible and equitable advancements in this promising field.

Benefits of synbio for agriculture:

- **Enhanced crop yields:** By engineering plants to have improved resistance to pests, diseases, and environmental stresses, synbio can help increase crop yields and ensure food security.

- **Improved nutritional content:** Genetic modifications can lead to the development of crops with enhanced nutritional profiles, such as biofortified crops, which contain increased levels of essential nutrients like vitamins and minerals.

- **Reduced environmental impact:** Synbio can lead to the development of crops that require fewer inputs, such as water, fertilizer, and pesticides, reducing the environmental impact of agriculture.

- **Climate change resilience:** Engineering crops to be more tolerant to drought, salinity, and extreme temperature fluctuations can help create more resilient agricultural systems in the face of climate change.

4: "Agricultural Biotechnology Market Size Growing at 9.4% CAGR Set to Reach USD 77.4 Billion By 2032," Globe Newswire, March 16, 2023.
5: "Global Synthetic Biology Market Is Projected to Grow at a 23% Rate Through the Forecast Period," EIN Presswire, March 1, 2023.

- **Sustainable biofuels and biomaterials:** Synbio can help develop plants that produce biofuels or biomaterials, reducing the reliance on fossil fuels and contributing to a more sustainable economy.

Challenges of synbio for agriculture:

- **Ethical and social concerns:** Genetic modification of organisms raises ethical considerations, such as the potential impact on biodiversity, the potential creation of "superweeds," and the monopolization of agricultural resources by large corporations.

- **Regulatory hurdles:** The development and commercialization of genetically modified organisms (GMOs) are subject to strict regulations, which can slow down the process and increase costs.

- **Public perception:** There is significant public skepticism and opposition to GMOs, driven by concerns about the potential health and environmental risks associated with their use.

- **Intellectual property issues:** The patenting of GMOs and related technologies can limit access to these innovations, particularly for smallholder farmers and researchers in developing countries.

- **Unintended ecological consequences:** The release of GMOs into the environment may have unintended ecological impacts, such as the potential for gene flow to wild relatives or the disruption of natural ecosystems.

Synbio techniques and technologies

Synbio tools enable or accelerate traditional biology techniques. In other words, it can be thought of as combining engineering concepts with scientific principles. Through the lens of agtech, some providers are developing synbio tools and platforms that are industry agnostic but have clear benefits in agriculture. Other providers are more clearly focused on solving agricultural challenges using synbio techniques as tools in a toolbox. Examples of synbio technologies used in agriculture include:

Genome editing

Genome editing technologies, such as CRISPR-Cas9, can be used to precisely modify the genetic code of plants or animals to produce desirable traits, such as improved disease resistance, higher yields, and better nutritional content—or in animals to improve health or correct genetic disorders. Some companies using genome-editing technologies include:

- **Pairwise:** Uses CRISPR-Cas9 technology to develop new plant varieties with desirable traits, such as improved taste, texture, and nutritional content.

- **Inari Agriculture:** Uses gene-editing technology to develop plant varieties that can produce higher yields and withstand environmental stress, such as drought and heat.

- **Hudson River Biotechnology:** Uses CRISPR-Cas9 technology for faster and more targeted plant breeding to achieve new varieties with higher yields and improved nutrient content, drought resistance, and other desired traits.

In addition to these companies, academic researchers and other companies are working on genome editing in agriculture. Technology has the potential to revolutionize the way we breed and grow crops. It could lead to the development of more nutritious crops that are more resilient to pests and disease, and better adapted to changing environmental conditions.

Microbe engineering/plant-microbe interactions

Synbio can be used to engineer plant-microbe interactions to improve crop growth, nutrient uptake, and resistance to pests and diseases. Microbes can be used in agriculture to enhance plant health and growth. For example, microbes can be engineered to produce plant growth hormones or to fix nitrogen in the soil, reducing the need for synthetic fertilizers.

Microbial engineering is the process of modifying microorganisms—such as bacteria, yeast, or fungi—to enhance their natural abilities or introduce new functionalities. This can be achieved using various genetic engineering techniques, including gene editing, gene insertion, or metabolic engineering.

Microbe engineering involves manipulating the microorganism's genome to achieve desired traits or functions, such as the production of valuable compounds, degradation of pollutants, or the ability to fix nitrogen for plant growth. The development of advanced genetic engineering tools, such as CRISPR/Cas systems and synbio approaches, has dramatically expanded the possibilities for microbe engineering in recent years. Companies using microbe engineering in agriculture include:

- **Indigo Agriculture:** Uses synbio to engineer microbes that live in the soil and improve crop growth by increasing the plant's ability to take up nutrients.

- **AgBiome:** Develops microbial solutions for agriculture. The company's products are designed to improve crop yields, reduce the use of pesticides, and protect crops from pests and diseases.

- **Pivot Bio:** Develops microbial nitrogen-fixing solutions for agriculture. The company's products are designed to reduce nitrogen fertilizer use and improve crop yields.

- **Loam:** Developing and commercializing a new technology for using engineered microbes to improve crop yields. The company's technology is based on a proprietary platform that allows for the precise delivery of engineered microbes to the root zone of plants. This allows the microbes to interact with the plant's roots in a way that is not possible with traditional methods of application.

The use of engineered microbes in agriculture has the potential to improve crop productivity, enhance nutrient availability, and reduce the reliance on chemical fertilizers and pesticides. However, several considerations need to be addressed to ensure the safe and effective application of these technologies:

- **Regulatory approval:** Engineered microbes must undergo rigorous safety testing and regulatory approval processes to ensure they do not pose risks to human health, the environment, or native ecosystems. Different countries have different regulatory frameworks for GMOs and navigating these regulations can be complex and time-consuming.

- **Environmental safety:** The potential for engineered microbes to spread beyond their intended application areas or to transfer their genetic modifications to other organisms in the environment is a concern. Researchers must carefully evaluate the potential ecological impacts and design containment strategies to minimize the risk of unintended consequences.

- **Resistance development:** Just as pests and pathogens can develop resistance to chemical pesticides and antibiotics, they may also develop resistance to biocontrol agents or engineered microbes. It is essential to monitor and manage resistance development to ensure the long-term effectiveness of these technologies.

- **Public perception:** The use of GMOs, including engineered microbes, is a controversial topic for some people. Addressing public concerns and promoting transparency and education about the benefits and risks of these technologies are crucial for their acceptance and adoption.

- **Intellectual property and accessibility:** Engineered microbes are often patented, which can limit their availability to farmers, particularly in developing countries. Ensuring equitable access to these technologies is essential to maximize their global impact on agriculture.

- **Compatibility with existing agricultural practices:** Engineered microbes must be compatible with existing agricultural practices, including crop varieties, management techniques, handling, and farming equipment. Successful integration will require collaboration among researchers, farmers, and industry stakeholders.

- **Cost-effectiveness:** The development and production of engineered microbes can be expensive. Ensuring that these technologies are cost-effective for farmers, particularly smallholder farmers in developing countries, is essential for widespread adoption.

RNA engineering

RNA interference (RNAi) is a groundbreaking biotechnological advancement that offers significant opportunities for the agricultural industry. By leveraging this naturally occurring mechanism—which regulates gene expression by targeting specific mRNA molecules for degradation—businesses can develop innovative crop varieties and pest management solutions with enhanced performance and reduced

environmental impact. The ability to selectively silence genes in plants, pests, and pathogens provides a targeted approach to crop improvement, pest control, and disease resistance, ultimately increasing crop yields and reducing the reliance on chemical pesticides and fertilizers.

RNAi technology presents an exciting avenue for growth and differentiation for businesses operating within the agricultural sector. By investing in the research and development of RNAi-based products, companies can expand their portfolios with environmentally friendly and sustainable solutions that meet the increasing demand for eco-conscious agricultural practices. Crop varieties engineered with RNAi technology can exhibit improved nutritional content, enhanced stress tolerance, and optimized plant architecture, providing farmers with more productive and resilient plants. Furthermore, RNAi-based pest and disease management strategies allow for targeted control, reducing the risks associated with broad-spectrum chemical applications. As the global population continues to grow, the agricultural industry must adapt to meet the increasing demand for food. RNAi technology offers a promising solution to address this challenge while minimizing environmental impacts. Companies developing RNAi solutions include:

- **Pebble Labs:** Uses RNAi to enhance crop yield, reduce the use of synthetic pesticides and antibiotics, and control disease vectors. Pebble Labs' approach involves using naturally occurring bacteria to deliver RNAi molecules to target organisms, such as pests, pathogens, or even the plants themselves, to modulate gene expression. This approach allows for targeted, environmentally friendly interventions with minimal off-target effects.

- **RNAiSSANCE AG:** Focused on developing and applying RNAi technology for agricultural purposes. The company's primary goal is to create environmentally friendly, RNAi-based products to control pests and diseases in agriculture. RNAiSSANCE AG's approach involves designing and producing double-stranded RNA (dsRNA) molecules that target specific genes in pests or pathogens. When these organisms come into contact with the dsRNA molecules, their target genes are silenced, leading to reduced pest or pathogen populations. This approach enables a targeted, environmentally friendly method of crop protection that aligns with the growing demand for sustainable agricultural practices.

- **Silvec Biologics:** Developing RNAi-based products for use against pests and diseases, such as soybean rust and rice blast. For example, dsRNA can be used to silence genes that are essential for the development of pests. This can lead to the death of the pest or prevent it from reproducing. The company's products are designed to be more environmentally friendly and effective than traditional pesticides.

These companies represent just a few examples of organizations exploring and investing in RNAi technology for agricultural applications. As research progresses and regulatory hurdles are cleared, more companies will likely enter the market and contribute to developing innovative, sustainable solutions for crop improvement, pest control, and disease resistance.

Protein engineering

Protein engineering is a field of biotechnology that involves designing, modifying, or creating proteins with specific properties, structures, or functions. This can be achieved through various methods, such as directed evolution, rational design, or computational protein design. Protein engineering aims to produce proteins with improved or novel functionalities that can be applied in diverse industries, including agriculture, medicine, and bioprocessing.

In agriculture, protein engineering has been used to develop solutions for a range of challenges, such as improving crop yield, enhancing resistance to pests and diseases, and reducing the environmental impact of farming practices. Some companies developing solutions for agriculture using protein engineering include:

- **Syocin Biotech:** Developing a platform for designing and constructing high-precision bactericidal proteins. The company's synbio platform can aid in the design and build of high-precision bactericidal proteins in a matter of months, not years. The platform is meant to develop agricultural bioproducts that precisely target plant bacterial pathogens that threaten world food availability. Syocin is currently developing biobactericides based on sophisticated proteins that can protect and cure fruit and vegetable crops from bacterial diseases in a precise way.

- **Pivot Bio:** Uses protein engineering as part of its development process for its nitrogen-producing microbial products for crop production. The company utilizes a proprietary approach to engineer beneficial microbes that can replace or reduce the need for synthetic nitrogen fertilizers. This approach involves modifying the genes and metabolic pathways of the microbes to optimize their nitrogen fixation capacity and performance in agricultural settings.

- **Yield10 Bioscience:** Develops seed traits and genetic technologies to enhance crop yield, stress tolerance, and carbon efficiency. It uses protein engineering to improve the activity and specificity of proteins involved in key metabolic pathways, such as photosynthesis and seed storage, to increase yield and improve crop quality.

These are just a few examples of companies that use protein engineering techniques in agriculture. As the field of agricultural biotechnology continues to advance, we can expect to see more companies using these techniques to develop new and improved crop varieties and agricultural products.

Biosensors

Biosensors are analytical devices that use biological molecules, such as enzymes or antibodies, to detect and measure the presence of specific compounds or analytes in a sample. They have a wide range of applications in agriculture, from monitoring soil health to detecting pathogens in crops and livestock.

In agriculture, biosensors can monitor various environmental and biological factors that affect plant growth and yield. For example, biosensors can detect soil nutrients, moisture levels, and pH, allowing farmers to adjust their fertilizer and irrigation practices to optimize crop growth. They can also detect the presence of plant pathogens, such as viruses, bacteria, and fungi, enabling farmers to take preventative measures to minimize crop damage and yield loss. Examples of companies deploying biosensors in agriculture include:

- **AgBiome:** Uses biosensors to identify and develop new biological products for crop protection and soil health. Their proprietary platform Genesis uses high-throughput screening and bioinformatics to identify novel microorganisms and molecules that can be used as biopesticides and biofertilizers.

- **Phytech:** Uses biosensors to monitor crop health and optimize irrigation in real time. Their platform PlantBeat uses sensors attached to the plants to monitor changes in plant physiology and water stress. This information is then used to optimize irrigation schedules and improve crop yield and quality.

- **Trace Genomics:** Uses biosensors and genomics to improve soil health and crop productivity. Their TraceCOMPLETE solution analyzes soil microbiome data using machine learning algorithms to identify beneficial microbial species and soil traits that can be used to optimize crop production.

- **AgroSustain:** Uses biosensors to develop natural, non-toxic solutions for plant disease control. Their AgroShelf+ technology uses biosensors to detect fungal growth on fruits and vegetables, allowing for early detection and treatment of plant diseases.

Biosensors offer a powerful tool for monitoring and managing various aspects of agriculture, from soil health and nutrient management to crop protection and food safety. By providing real-time and on-site measurements, biosensors can help farmers make informed decisions about crop management, leading to improved efficiency and crop yields, while ensuring the safety and quality of the food products.

Other technologies

Metabolic engineering involves designing and optimizing metabolic pathways in organisms to produce specific compounds of interest. In agriculture, metabolic engineering is used to develop crops with improved yield, quality, and sustainability and to develop novel bio-based products for various applications. It can be used to enhance crop performance, develop sustainable solutions, and produce valuable compounds for a range of industries. By engineering the metabolic pathways involved in specific traits, such as stress tolerance, disease resistance, or nutritional content, researchers can improve crop performance and enhance the nutritional value of food products. Furthermore, metabolic engineering can help optimize various aspects of agricultural production, such as nutrient management and waste reduction, leading to more sustainable and efficient agricultural practices. Companies using metabolic engineering include Pivot Bio, Agrivida, and Caribou Biosciences.

DNA synthesis is the process of building custom DNA sequences from scratch using chemical building blocks. In agriculture, DNA synthesis has many applications, including the development of genetically modified crops and the production of synbio tools. Researchers can create crops with specific traits by synthesizing custom DNA sequences, such as improved yield, disease resistance, and nutritional content. Synbio tools, like biosensors, can also be created using DNA synthesis, allowing farmers to monitor and manage various aspects of crop production. DNA synthesis is a valuable tool for agriculture; it allows for the rapid development of custom DNA sequences, enabling researchers to create novel solutions for various challenges in the field. Companies using DNA synthesis include Benson Hill, Pairwise, and AgBiome.

Directed evolution is a technique to engineer proteins and enzymes with desired traits. In agriculture, directed evolution improves crop performance, nutrient use efficiency, and resistance to environmental stressors. By subjecting proteins to controlled mutagenesis and selection, researchers can identify variants with improved activity or specificity. These variants can be used to optimize key metabolic pathways in crops, leading to enhanced yield and stress tolerance. Directed evolution can also be used to develop novel enzymes and proteins for various applications in agriculture, such as biopesticides or biofuels. Overall, directed evolution is a powerful tool for developing new and improved solutions for various challenges in agriculture. Companies using directed evolution include Amfora, Joyn Bio, and Novozymes.

Cell-free systems are a form of synbio that involves creating biological systems outside living cells, typically using extracts from cells stripped of their cellular membranes. In agriculture, cell-free systems have many applications, including the development of biosensors, production of high-value compounds, and engineering of metabolic pathways. For example, cell-free systems can be used to create custom enzymes for agricultural applications or to produce compounds such as plant-derived flavors or fragrances. Cell-free biosensors can be developed to monitor soil health or detect plant pathogens, and they can be designed to be portable and cost-effective. Overall, cell-free systems offer a versatile and powerful tool for developing novel solutions in agriculture, enabling researchers to create custom biological systems that can address a wide range of challenges in the field. Companies using cell-free systems include OriCiro, Debut Biotechnology, and GreenLight Biosciences.

Select VC-backed company highlights

Pivot Bio

- Founded: 2010
- Employees: 398+
- Total VC raised: $616.7 million
- Last financing: $430.0 million in Series D funding
- Last financing valuation: $1.7 billion

Overview

Pivot Bio is a pioneering biotechnology company that focuses on developing innovative and sustainable agricultural solutions to increase crop productivity while reducing the environmental impact of farming. Founded in 2010 by Karsten Temme and Alvin Tamsir, the company was established to address the inefficiencies and environmental challenges associated with synthetic nitrogen fertilizer usage in agriculture.

Pivot Bio's primary product, known as Pivot Bio PROVEN™, is a nitrogen-producing microbe that is applied to the seeds of crops such as corn, wheat, and rice. These microbes form a symbiotic relationship with the plants, providing a natural and continuous source of nitrogen, while reducing the need for synthetic nitrogen fertilizers. This innovative approach offers a more sustainable and efficient alternative to conventional fertilizers, improving crop yields and reducing environmental pollution.

Leadership

The leadership team at Pivot Bio includes CEO and Co-founder Dr. Karsten Temme, who holds a Ph.D. in Biological Engineering from the University of California, San Francisco, and has extensive experience in synthetic biology and biotechnology. Other key members of the leadership team include Chief Science Officer and Co-founder Alvin Tamsir, Chief Operating Officer Lisa Nunez Safarian, and CFO Doug Jeffries—each bringing a wealth of experience from the biotechnology, agriculture, and business sectors.

Competition

In the competitive landscape, Pivot Bio faces competition from other agricultural biotechnology companies, including Indigo Ag, Azotic Technologies, and Intrinsyx Bio. These companies also focus on developing sustainable agricultural solutions, such as microbial seed treatments, to improve crop health and productivity. However, Pivot Bio's unique nitrogen-producing microbe technology and strong commitment to sustainability set it apart from its competitors.

Outlook

As the demand for sustainable agricultural solutions continues to grow in the face of global food security and environmental concerns, the company is well-positioned to capitalize on this trend. Pivot Bio aims to expand its product offerings, enter new markets, and forge strategic partnerships to increase its market share and global impact. In doing so, the company has the potential to revolutionize the agriculture industry by reducing the reliance on synthetic fertilizers and contributing to a more sustainable and productive global food system.

Inari

- Founded: 2016
- Employees: 285+
- Total VC raised: $476.0 million
- Last financing: $124.0 million in Series E financing
- Last financing valuation: $1.5 billion

Overview

Inari is an innovative agricultural technology company with a mission to transform the global food system through gene-editing technology. Founded in 2016 by Flagship Pioneering, Inari's vision is to create a more sustainable, resilient, and equitable food system by developing high-performing seeds that require fewer inputs and have a reduced environmental impact. Utilizing advanced CRISPR gene-editing tools and computational biology, Inari aims to develop crops with enhanced yield potential, improved resistance to pests and diseases, and greater adaptability to climate change.

Inari's business model revolves around creating proprietary seed varieties using its cutting-edge SEEDesign platform, which combines gene-editing technology, data science, and advanced breeding techniques. The company collaborates with seed producers and distributors, licensing its seed varieties and sharing in the value created for farmers. By offering seeds that are better suited to local growing conditions and have reduced input requirements, Inari's products have the potential to increase profitability for farmers while minimizing the environmental footprint of agriculture.

Leadership

The leadership team at Inari is composed of seasoned professionals with diverse expertise in agriculture, biotechnology, and business. Ponsi Trivisvavet, the CEO and director, has a wealth of experience in the agriculture industry, having previously served as the chief operating officer of Indigo and president of Syngenta Seeds North America. Other key leadership team members include Chief Sales Officer Dr. Catherine Feuillet, Chief Financial Officer Stuart Brown, and Chief Information and Data Officer Dr. Rania Khalaf—each of whom brings extensive experience from the biotechnology, agriculture, and business sectors.

Competition

In the competitive landscape, Inari faces competition from other agricultural biotechnology companies focusing on gene-editing technologies, such as Calyxt, Benson Hill, and Corteva Agriscience. These companies are also developing advanced breeding technologies and gene-edited crops to address various challenges in agriculture. However, Inari's unique SEEDesign platform and focus on sustainability and local adaptation set it apart from its competitors.

Outlook

Inari has a promising future as the demand for sustainable and resilient agricultural solutions continues to grow in response to global food security and climate change challenges. The company plans to expand its product portfolio, enter new markets, and form strategic partnerships to increase its market share and impact on the global food system. By leveraging its gene-editing technology and expertise, Inari has the potential to redefine the agriculture industry, contributing to a more sustainable, productive, and equitable food system.

Pebble Labs

- Founded: 2017
- Employees: 26+
- Total VC raised: $26.7 million
- Last financing: $18.7 million in Series A financing
- Last financing valuation: $335.0 million

Overview

Pebble Labs is a biotechnology company committed to developing sustainable and innovative solutions to address critical challenges in agriculture, aquaculture, and public health. Founded in 2016 by Edward Cheung, Michael Harrison, Kimberly Landry Harrison, and Martin Pasek in Los Alamos, New Mexico, the company's vision is to harness the power of biology to create environmentally friendly alternatives to traditional chemical-based approaches, such as pesticides and antibiotics.

Pebble Labs' proprietary Directed Biotics™ platform uses naturally occurring bacteria to produce RNA molecules that can safely and selectively target harmful pathogens, pests, or diseases without impacting beneficial organisms or the environment. The company focuses on creating products that improve crop health, increase yield, and enhance food safety, while minimizing the use of synthetic chemicals and promoting sustainable practices.

Leadership

At the helm of Pebble Labs, CEO Dr. Rebecca White leads an accomplished leadership team. With a distinguished career in the life sciences field, Dr. White has held high-ranking positions in notable companies such as Trait Biosciences and Algae Biomass Organization. Her expertise is complemented by other essential members of the team, including Dr. Pedro Costa Nunes, the head of research

strategy, and Dr. Stephanie Wedryk, the vice president of development. Both Dr. Nunes and Dr. Wedryk bring a vast array of knowledge and experience from the biotechnology, agriculture, and business sectors, further strengthening Pebble Labs' leadership foundation.

Competition

In the competitive landscape, Pebble Labs faces competition from other biotechnology companies focused on developing sustainable solutions for agriculture and aquaculture, such as Indigo Ag, Marrone Bio Innovations, and Aquabounty Technologies. These companies are also working on innovative biological approaches to improve crop and aquatic species health, increase yield, and reduce the environmental impact of food production. However, Pebble Labs' unique Directed Biotics™ platform and its broad applicability across multiple industries differentiate it from its competitors.

Outlook

The outlook for Pebble Labs appears promising, as the demand for sustainable and environmentally friendly solutions in agriculture, aquaculture, and public health continues to grow. The company plans to expand its product offerings, enter new markets, and form strategic partnerships to increase its market share and global impact. By leveraging its groundbreaking Directed Biotics™ technology, Pebble Labs has the potential to transform the way we approach food production and public health, contributing to a more sustainable and eco-friendly world.