

The Engineered World: An Expert Report on Synthetic Biology and the New Bioeconomy

I. Executive Summary: The Convergence of Biology and Engineering

Synthetic biology (SynBio) represents a paradigm shift at the intersection of life sciences, engineering, and computer science. Defined as the design and construction of novel biological parts, devices, and systems, or the re-engineering of existing biological systems for predetermined, useful purposes, SynBio applies standardized, rigorous engineering principles—modularity, prediction, and optimization—to living organisms.¹ This approach moves science beyond merely observing or modifying nature toward truly programmable biology.

The foundational technology fueling this revolution is the ability to rapidly and cost-effectively "write" custom DNA, effectively treating genetic code as software for living cells. This capability is catalyzing a new bioeconomy expected to profoundly transform critical sectors including medicine, materials science, manufacturing, and food production.

Market Momentum and Economic Imperative

The economic trajectory of synthetic biology underscores its role as a fundamental technology driving the Fourth Industrial Revolution. The global synthetic biology market has been experiencing explosive growth, propelled by relentless advancements in DNA synthesis and sequencing technologies, increasing private and governmental investment, and a worldwide demand for sustainable biomanufacturing solutions.²

Market valuations demonstrate this robust financial interest. In 2024, the global market size was estimated between US\$19.3 billion.⁵ Projections indicate a sustained, robust Compound Annual Growth Rate (CAGR), often exceeding 20%, positioning the market to reach valuations between US\$74.7 billion by 2029 or 2031.¹ This exponential growth is fundamentally underpinned by the industrialization of the biological design-build-test cycle. The scalability afforded by standardized tools and platforms is analogous to the mass production capabilities achieved by the semiconductor industry, enabling cost reduction and the deployment of biological solutions across a multitude of applications. The following table summarizes key market projections:

Synthetic Biology Market Growth Projections (2023-2031)

Metric	2023 Value (USD)	2029/2031 Value (USD)	Projected CAGR	Source/Implication
MarketsandMarkets	\$11.97 Billion	\$31.52 Billion (by 2029)	20.6% (2024-2029)	Focus on core technology adoption. ²
BCC/Global Report	\$15.4 Billion	\$61.6 Billion (by 2029)	26.1% (2024-2029)	Higher valuation reflects inclusion of downstream therapeutic/industrial products. ⁵
Transparency Mkt Research	\$10.7 Billion (2021)	>\$74.7 Billion (by 2031)	21.3% (2022-2031)	Indicates sustained, long-term exponential growth. ¹

II. Synthetic Biology Fundamentals: Defining the Design Space

Understanding synthetic biology requires differentiating it from traditional genetic engineering. While both fields involve manipulating genetic material, their scope, methodology, and ultimate objectives diverge significantly.

Beyond Genetic Modification: SynBio vs. Genetic Engineering

Traditional **Genetic Engineering (GE)** is primarily viewed as a "toolbox for genetic modification of existing living organisms".⁸ It typically involves modifying an organism by adding, removing, or altering a small number of genes using established molecular techniques, such as transferring a gene from one species to another to confer a single new trait. The focus remains on tweaking an existing natural system.

Synthetic Biology (SynBio), however, embodies a rigorous engineering discipline. It centers on the methods of designing and constructing *de novo* biological parts, devices, and systems, frequently utilizing predominantly *synthesized* molecules (e.g., DNA sequences, microRNAs, proteins).⁸ The mindset is not one of modification, but of foundational design and manufacturing. Synthetic biologists aim to create novel biological circuits and functions that may not exist in nature, overcoming the inherent unpredictability and complexity of natural systems by imposing structure and standardization.

The fundamental difference lies in the level of complexity and scale. Traditional GE often involves custom, organism-specific approaches that are challenging to scale. Synthetic biology overcomes this scale barrier by treating DNA as code that can be rapidly synthesized, assembled, and debugged using computational tools and high-throughput automation.³ This industrialization of biology is what makes large-scale biomanufacturing feasible and underpins the exponential growth projections for the market.

Conceptual Comparison: Genetic Engineering vs. Synthetic Biology

Feature	Genetic Engineering (Traditional)	Synthetic Biology (SynBio)
Primary Goal	Modify existing biological systems (e.g., adding one gene to an organism).	Design and construct novel biological parts, devices, and systems.
Methodology Focus	Modifying existing DNA using restriction enzymes.	Design, synthesize, and assemble new DNA sequences and circuits.
Core Component Source	Predominantly derived from natural organisms.	Predominantly <i>synthesized</i> molecules (DNA sequences, microRNAs, proteins). ⁸

The Core Philosophy: The Design-Build-Test-Learn Cycle

Synthetic biology adopts the iterative cycle used in traditional engineering. This Design-Build-Test-Learn (DBTL) framework is crucial for optimizing outcomes in unpredictable biological systems. Advances in enabling technologies—including high-throughput automation, sophisticated data science, and rapid DNA synthesis—are continuously accelerating this cycle, allowing scientists to rapidly test thousands of genetic designs and refine their understanding of biological mechanisms.³ This systematic, engineering-based approach is essential for reducing the burden of synthetic networks on endogenous cellular circuits and moving toward truly predictable biological outcomes.³

III. The Foundational Toolkit: Enabling Technologies

The power of synthetic biology stems from a robust and rapidly evolving toolkit, which allows researchers to program cellular behavior with unprecedented precision and scale.

DNA Writing: The Industrialization of Gene Synthesis

The ability to create custom, long stretches of DNA accurately and affordably is arguably the single most critical enabling factor for synthetic biology. Historically, gene synthesis was slow and expensive, posing severe limitations to the scope of biological research.¹⁰

Companies specializing in this area, such as Twist Bioscience, have transformed DNA writing by applying rigorous engineering principles derived from the semiconductor industry. Their proprietary silicon-based DNA synthesis platform miniaturizes the chemistry necessary for DNA synthesis, allowing the production of high-quality synthetic DNA at scale.¹⁰ This platform increases throughput by a factor of 1,000 and reduces reaction volumes by a factor of 1,000,000 compared to traditional methods, thus dramatically lowering the turnaround time and price per base (with some products starting as low as 7¢ per base pair).¹⁰ This technological leap industrializes the production of DNA, effectively creating the "printing press" for the bio-revolution. The decline in the cost of DNA synthesis, coupled with similar advances in DNA sequencing, is a primary catalyst driving the overall market growth.²

Standardized Biological Parts and Modular Assembly

The core tenet of engineering is modularity. In synthetic biology, this is achieved through standardized components that can be assembled interchangeably. The **BioBrick standard** is a foundational example, defining standardized prefix and suffix sequences that flank genetic parts—such as the promoter (P), ribosomal binding site (RBS), coding sequence (CDS), and terminator (T).¹²

This system resolves a key historical challenge in molecular cloning, where traditional methods required matching specific restriction sites in both the part and the plasmid backbone. By synthesizing sequences with standardized restriction sites (EcoRI, XbaI, SpeI,

PstI), the BioBrick concept enables standardized assembly and part exchangeability, paving the way for constructing increasingly complex genetic "devices" with reduced effort and time.¹²

Cellular Programming: Designing Genetic Circuits

Genetic circuits allow synthetic biologists to program cells with novel, complex functions, much like designing an electronic microchip.¹² These circuits are constructed from standardized biological components with interchangeable inputs and outputs, controlling how genes are expressed in response to specific conditions.

These circuits often function based on **logic gates**, drawn directly from engineering principles. For example, an **AND Gate** is designed to produce an output signal only when two specific input signals are present. In a cellular system, Input 1 (e.g., a specific metabolite) and Input 2 (e.g., a specific environmental temperature) activate separate promoters. These promoters, in turn, drive the expression of two corresponding proteins (A and B). Only when both Protein A and Protein B are successfully expressed can they cooperate to activate a third, final promoter, which then drives the expression of the desired output, such as Green Fluorescent Protein (GFP) or a therapeutic compound.¹² This design enables highly conditional and precise control over cellular behavior, essential for advanced applications like targeted drug delivery or smart biosensors.

Precision Editing Systems: The Evolution of Genome Control

CRISPR/Cas9 is a widely adopted gene-editing tool that has accelerated the field, enabling researchers to make precise changes in an organism's DNA, such as conferring disease resistance in crops.¹³ However, newer, more refined techniques are emerging to overcome CRISPR's limitations.

Base Editing is an emerging class of precision genetic medicines, exemplified by the technology developed by companies like Beam Therapeutics. Base editors are often likened to a "pencil" that enables erasing and rewriting one letter of the genome at a time, rather than the "scissors" metaphor often applied to CRISPR/Cas9.¹⁴ The crucial advantage is that base editors enable precise, predictable, single-letter base changes (e.g., cytosine-to-thymine or adenine-to-guanine) without necessitating a double-stranded DNA break (DSB).¹⁵ Avoiding the DSB mitigates the unwanted consequences associated with these breaks, such as unpredictable insertions and deletions (indels) and larger-scale genomic rearrangements.¹⁵ Base editing applications are broad, including correcting single point mutations, writing in protective genetic variants, or modulating the expression of disease-causing genes by editing regulatory elements.¹⁴

IV. Global Applications: Revolutionizing Industry and Health

Synthetic biology is being deployed across the global economy to address complex challenges, resulting in profound transformations in four primary areas: healthcare, manufacturing, agriculture, and energy.

Precision Medicine and Therapeutics

Healthcare and pharmaceuticals represent the fastest-growing segment in the synthetic biology market, fueled by the rising use of these tools in precision medicine and vaccine development.²

Genetic medicine has already demonstrated major breakthroughs. CRISPR/Cas9 technology, developed through collaborations such as that between CRISPR Therapeutics and Vertex Pharmaceuticals, has yielded CASGEVY™ (exagamglogene autotemcel), the first-ever regulatory approved CRISPR-based therapy for certain eligible patients with sickle cell disease or transfusion-dependent beta thalassemia.¹⁶ Further advancements in this sector involve engineering living cells and cell-free systems for the on-demand production of diagnostics, novel therapeutics, protein-based drugs, and regenerative medicines.³

Delivery strategies for these advanced medicines are also crucial. For *ex vivo* applications (where cells are removed, edited, and returned to the body), such as editing blood and immune cells, electroporation is a clinically validated method. For *in vivo* delivery (directly into the body), nonviral delivery modalities like lipid nanoparticles (LNPs) are used, initially targeting organs such as the liver.¹⁴ Engineered bacteria-based platforms, nanoparticles, and organoids are also under investigation as advanced drug delivery vehicles.¹⁷

Sustainable Manufacturing and Advanced Materials

Synthetic biology is driving a manufacturing revolution by establishing bio-based production systems that reduce reliance on petrochemicals and minimize environmental impact.² Organisms, often microbes like yeast or bacteria, are engineered as "cell factories." They metabolize inexpensive feedstocks and are programmed to release specific metabolic byproducts that serve as industrial chemicals or materials.¹⁸

For instance, microorganisms have been engineered to produce a chemical used in rubber tire production, a substance previously derivable only from petroleum.¹⁸ This transition from petroleum-derived materials to sustainable, bio-based compounds is highly valued across industries.² In the realm of specialty chemicals and materials, synthetic biology enables the creation of molecules such as rose oil in engineered yeast, providing a sustainable and environmentally benign alternative to traditional agricultural harvesting.¹⁷ Additionally, scientists have integrated spider DNA into silkworms to produce ultra-lightweight,

super-strong silk, showcasing the potential for novel performance materials inspired by nature but improved by engineering.¹⁹ The shift toward bio-based production significantly increases supply chain stability, moving the production of complex, high-value molecules from climate-sensitive agriculture into controlled, predictable bioreactor environments.

Food, Agriculture, and Cellular Agriculture

To meet the global demand for nutritious and sustainable food, synthetic biology provides numerous solutions, ranging from crop enhancement to entirely new production methods.

Microorganisms are engineered to improve nutritional value, such as increasing the vitamin content in fermented foods like yogurt and cheese.¹³ Furthermore, engineered strains of yeast and bacteria are used for the commercial-scale production of high-value food ingredients traditionally sourced from plants, including the stevia sweetener and the heart-healthy antioxidant resveratrol.¹³

In traditional agriculture, genome editing technologies like CRISPR are showing promise in enhancing crop resilience. These tools are used to confer resistance in crop plants, such as wheat, against devastating fungi that affect yield.¹³ CRISPR technology is also being used to address food safety, such as turning off the peanut genes responsible for allergic reactions to develop hypoallergenic products.¹³

Beyond traditional farming, **Cellular Agriculture** leverages synthetic biology to produce foods with tailored nutritional profiles, longer shelf life, and fewer harmful ingredients.¹³ This includes the engineering of microalgae, such as *Chlorella*, to generate oils and butter for food applications.¹³ Moreover, engineered biosensors can enrich soil or feedstock, detecting pathogens or contaminants and enhancing the quality of both plant and animal food products.¹³

Environmental Remediation and Energy

Synthetic biology contributes to environmental remediation and the quest for sustainable energy. The first patent in synthetic biology, issued in 1981, involved bacteria modified to clean up oil spills.¹⁸ Today, the field continues to focus on engineering organisms for environmental applications, including the use of biosensors to enrich soil and the modification of organisms to restore ecosystems, such as engineering American chestnut trees to resist the deadly blight.¹⁸ In bioenergy, engineered microorganisms are being developed for biofuel production (e.g., biobutanol, a higher energy density alternative to ethanol) and next-generation biomanufacturing that utilizes alternative feedstocks like agricultural waste or carbon dioxide.⁹

V. The Commercial Landscape: Publicly Traded USA Synthetic Biology Players

Investment in synthetic biology has solidified a cohort of publicly traded companies in the United States that are driving the commercialization and industrialization of the field. These companies generally fall into distinct strategic roles: platform providers, core technology suppliers, and therapeutic developers.

Platform and Foundational Technology Providers

Ginkgo Bioworks (NYSE: DNA) is recognized as a leading horizontal platform for cell programming and is often called the "Organism Company".²¹ Ginkgo offers flexible, end-to-end services, leveraging advanced software and hardware in its foundries to solve challenges across highly diverse markets, including pharmaceuticals, food, agriculture, and industrial chemicals.²¹ The company designs organisms that produce specific substances or execute unique functions by engineering, editing, and printing DNA.²² A critical distinction is that Ginkgo focuses on enhancing its partners' capabilities through its platform rather than developing final products directly.²² Furthermore, Ginkgo Biosecurity is building and deploying infrastructure to predict, detect, and respond to biological threats, showcasing strategic diversification into national security and resilience.²³

Twist Bioscience Corporation (NASDAQ: TWST) serves as an indispensable core technology supplier, industrializing DNA synthesis. Twist's proprietary silicon-based DNA writing platform overcomes the traditional limitations of throughput, scalability, and cost in gene synthesis.¹⁰ By applying rigorous engineering principles and semiconductor manufacturing infrastructure, Twist can produce high-quality, high-fidelity synthetic DNA, including NGS-verified clonal genes, at high throughput, significantly accelerating the research and development cycles of its partners, including Ginkgo Bioworks.¹⁰ The ability of Twist to offer rapid and cost-effective DNA synthesis at scale is the primary financial enabler for the entire synthetic biology ecosystem.

Genetic Medicine Developers

CRISPR Therapeutics AG (NASDAQ: CRSP) is a biopharmaceutical company focused on creating transformative gene-based medicines for serious diseases.²⁵ The company centers its therapeutic strategy on the CRISPR/Cas9 gene-editing system, targeting areas such as hemoglobinopathies, immuno-oncology, autoimmune disorders, and *in vivo* applications.²⁶ Its landmark achievement is the development of CASGEVY™ (exagamglogene autotemcel) in collaboration with Vertex Pharmaceuticals, representing the first regulatory approval of a CRISPR-based therapy.¹⁶ CRISPR Therapeutics is also expanding its capabilities beyond core gene editing, for example, through a collaboration with Sirius Therapeutics to develop small interfering RNA (siRNA) therapies, broadening its therapeutic toolkit for gene-based medicines.²⁵

Beam Therapeutics (NASDAQ: BEAM) is focused on advancing science through precision genetic medicines, particularly using **Base Editing** technology.²⁷ Beam's proprietary base editors (cytosine and adenine) are engineered to create precise, predictable genetic outcomes without the high risk associated with double-stranded DNA cuts.¹⁵ The company is building a broad pipeline of investigational medicines designed to correct disease-causing point mutations, write in protective genetic variations, or modulate gene function by editing regulatory elements.¹⁴ Beam's delivery strategy includes clinically validated technologies like electroporation for *ex vivo* editing and nonviral lipid nanoparticles (LNPs) for direct *in vivo* delivery.¹⁴

Market Context: Commercialization Hurdles

While the technological promise is immense, the transition from successful research and development to sustainable, profitable commercial manufacturing remains a significant hurdle. This challenge is exemplified by the case of **Amyris, Inc.** Though historically recognized as a leader in industrial biofermentation for sustainable ingredients¹, Amyris and certain domestic subsidiaries initiated voluntary Chapter 11 bankruptcy proceedings in August 2023.²⁹ The restructuring, confirmed in early 2024, aimed to improve the company's financial structure and streamline its business portfolio to refocus on core competencies in R&D and the scale-up of biofermentation-derived sustainable ingredients.²⁹ This event serves as a critical indicator that technological superiority alone does not guarantee commercial success; the successful scaling and financial management of large-scale biomanufacturing processes are equally decisive factors.

Profile of Select Publicly Traded USA Synthetic Biology Companies

Company (Ticker)	Primary Focus Area	Key Technology/Platform	Market Role	Key Commercial Development
Ginkgo Bioworks (DNA)	Cell Programming Services	Horizontal Foundry Platform, Automated Biosecurity	R&D Platform Provider ²²	Strategic partnerships across Pharmaceuticals and Agriculture. ²¹
Twist Bioscience (TWST)	DNA Synthesis/Tools	Silicon-based High-Throughput DNA Writing	Core Technology Supplier ¹⁰	Rapid, cost-effective gene fragment and gene synthesis. ¹¹
CRISPR Therapeutics (CRSP)	Gene Editing Therapeutics	CRISPR/Cas9 System	Therapeutic Developer ¹⁶	First approved CRISPR-based therapy (CASGEVY™). ¹⁶
Beam Therapeutics (BEAM)	Precision Genetic Medicine	Base Editing (Single-letter changes without DSB)	Therapeutic Developer ¹⁴	Focus on correcting point mutations without double-stranded cuts. ¹⁴

VI. Governance, Ethics, and Risk Management

The profound and accelerating capabilities of synthetic biology bring with them serious safety risks and complex ethical dilemmas that demand robust governance frameworks. These challenges generally fall into the categories of biosafety and biosecurity.

Biosafety Concerns: Managing Unintentional Release

Biosafety pertains to the risk of accidental or unintentional harm caused by synthetic organisms (SOPs) during research, manufacturing, or transport.³¹ Given that synthetic biology facilitates the creation of entirely novel forms of life, the unintentional release of these organisms could pose serious health risks to laboratory personnel and surrounding communities, along with threats to the ecological environment.³¹

The increasing accessibility of core synthetic biology tools makes this risk more severe than with conventional biotechnology. If regulations and containment protocols fail to evolve at the same pace as technological accessibility, the potential for ecological disruption from accidentally released synthetic organisms increases, underscoring the necessity of enhanced technical biocontainment capabilities.³¹

Biosecurity Threats: The Dual-Use Dilemma

Biosecurity addresses the malicious use or abuse of synthetic organisms, such as bioterrorism.³¹ The dual-use nature of synthetic biology presents a unique threat: the same technologies used to engineer living cells to treat disease *within* the human body are also capable of creating novel or enhanced bioweapons.¹⁹ The intentional misuse of this technology has the potential to cause irreversible and devastating damage to human health and the environment.³¹

Since core enabling tools like DNA synthesis are becoming cheap and widely distributed, relying solely on reactive punishment is insufficient. This technological democratization necessitates the establishment of sophisticated, preventative infrastructure capable of predicting and detecting biological threats before they are realized. Legal frameworks must continually be updated to fill regulatory gaps, ensuring that technical lists identifying materials and equipment usable for bioweapons are current, and that malicious acts are met with severe penalties.³¹

Ethical Governance: Guiding Responsible Innovation

To ensure that the advancement of synthetic biology remains benevolent and centered on human welfare, ethical considerations must be integrated throughout the entire technology development process.³¹ Governing the field responsibly requires adherence to core ethical principles:

1. **Human-centeredness:** The ultimate goal of synthetic biology applications must be to value and respect human life and enhance human health and wellbeing.³¹
2. **Non-maleficence:** This is the most fundamental principle, requiring that synthetic biology research and application adhere strictly to the mandate of "do no harm".³¹
3. **Sustainability:** Considering the long-term impact on society and the environment, promoting applications that are ecologically sound.³¹
4. **Reasonable Risk Control:** Implementing proactive countermeasures, strengthening ethical review, and improving legal safeguards through top-level design to control all identified safety risks.³¹

VII. Conclusion and Strategic Outlook

Synthetic biology is rapidly transitioning from a nascent academic pursuit to an industrialized engineering discipline, positioning it as one of the most transformative fields in life sciences today.² The synthesis of advancements in DNA writing, modular design (BioBricks), and powerful genome editing (CRISPR and Base Editing) has lowered the cost and increased the speed of biological R&D, making cellular programming a reality.

The market has responded with enthusiasm, projecting continuous robust growth driven by high demand in pharmaceuticals, sustainable manufacturing, and cellular agriculture. Key publicly traded companies in the US are capitalizing on this growth by specializing either in core enabling tools (Twist Bioscience), end-to-end R&D platforms (Ginkgo Bioworks), or high-precision therapeutic development (CRISPR Therapeutics, Beam Therapeutics).

The future trajectory of synthetic biology is focused on developing increasingly complex systems—moving from simple genetic circuits to miniaturized genomes, expanded genetic code, and reprogrammed metabolic pathways.⁹ Strategic development aims to improve the predictability of biological outcomes by integrating high-throughput automation and advanced data science, reducing the unpredictable burden synthetic systems place on host cells.³ However, the commercial reality, as demonstrated by restructuring events in the sector, indicates that the scientific mastery must be matched by operational excellence and sound financial strategy to successfully scale biomanufacturing. Geopolitically, the field's capacity to revolutionize critical sectors has spurred major state-sponsored research programs worldwide, confirming synthetic biology as a central pillar of global economic and strategic competition.⁷

VIII. Read More (Sources)

The following sources were utilized in the preparation of this report:

⁸url:

https://www.researchgate.net/post/What_is_the_difference_between_genetic_engineering_and_synthetic_biology#:~:text=The%20term%20%22Synthetic%20biology%22%20refers,of%20methods%20for%20designing%20and

¹²url: <https://www.mdpi.com/2674-0583/3/3/11>

¹³url:

<https://www.genscript.com/applications-of-synthetic-biology-in-food-industry-and-agriculture.html>

¹⁷url: https://en.wikipedia.org/wiki/Synthetic_biology

³¹url: <https://pmc.ncbi.nlm.nih.gov/articles/PMC10628459/>

⁴url:

<https://www.nasdaq.com/articles/3-promising-genomics-synthetic-biology-stocks-spotlight-2025>

²¹url: <https://www.ginkgo.bio/about>

³²url: <https://aws.amazon.com/solutions/case-studies/ginkgo-bioworks-case-study/>

²³url: <https://www.sojitz.com/en/news/article/topics-20240515.html>

²²url:

<https://www.etftrends.com/disruptive-technology-channel/innovation-scale-ginkgo-bioworks-approach-revolutionizing-industries/>

³³url:

<https://www.twistbioscience.com/products/genes/gene-synthesis#:~:text=Product%20Sheet,-Clonal%20Genes%20Product&text=Twist%20Bioscience%20is%20transforming%20gene,time%20and%20price%20per%20base.>

¹¹url: <https://www.twistbioscience.com/products/genes/gene-synthesis>

¹⁰url: <https://www.twistbioscience.com/technology>

²⁶url: <https://crisprtx.com/about-us/partnerships>

¹⁶url: <https://crisprtx.com/>

²⁵url:

<https://crisprtx.com/about-us/press-releases-and-presentations/crispr-therapeutics-and-sirius-therapeutics-announce-multi-target-collaboration-to-develop-novel-sirna-therapies>

¹⁵url: <https://beamtx.com/science/base-editing/>

²⁷url: <https://beamtx.com/>

²⁸url: <https://beamtx.com/science/>

¹⁴url: <https://beamtx.com/science/base-editing-applications/>

⁶url:

<https://www.marketsandmarkets.com/ResearchInsight/synthetic-biology-market-regional-insights.asp#:~:text=Synthetic%20Biology%20Market%3A%20Innovations%20Driving%20the%20Next%20Biotech%20Revolution,-DOWNLOAD%20PDF&text=The%20global%20synthetic%20Obiology%20market,US%2431.52%20billion%20by%202029>.

²url:

<https://www.marketsandmarkets.com/ResearchInsight/synthetic-biology-market-regional-insights.asp>

⁹url: <https://pmc.ncbi.nlm.nih.gov/articles/PMC9744534/>

⁷url: <https://www.bccresearch.com/pressroom/bio/synthetic-biology-market>

³url: <https://pmc.ncbi.nlm.nih.gov/articles/PMC6692427/>

¹⁸url:

<https://hudsonlabautomation.com/synthetic-biology-applications-medical-industrial-and-more/>

²⁰url: <https://www.ncbi.nlm.nih.gov/books/NBK84446/>

¹⁹url: <https://www.gao.gov/products/gao-23-106648>

⁴url:

<https://www.nasdaq.com/articles/3-promising-genomics-synthetic-biology-stocks-spotlight-2025>

⁵url:

<https://crisprmedicineneeds.com/press-release-service/card/synthetic-biology-global-market-report-2024-featuring-profiles-of-market-leaders-ginkgo-bioworks-a/>

²⁴url:

<https://investors.twistbioscience.com/news-releases/news-release-details/twist-bioscience-and-ginkgo-bioworks-revise-collaboration>

¹url:

<https://www.pharmiweb.com/press-release/2024-12-11/synthetic-biology-market-expected-to-surpass-usd-747-billion-by-2031-amid-rapid-advancements-in-biotechnology-tmr>

²⁹url: <https://cases.stretto.com/amyris/>

³⁴url: <https://greenchemicalsblog.com/amyris-rebuilds-post-bankruptcy/>

³⁰url:

<https://www.prnewswire.com/news-releases/amyris-announces-operational-and-financial-restructuring-to-advance-strategic-transformation-301897438.html>

¹²url: <https://www.mdpi.com/2674-0583/3/3/11>

¹³url:

<https://www.genscript.com/applications-of-synthetic-biology-in-food-industry-and-agriculture.html>

³¹url: <https://pmc.ncbi.nlm.nih.gov/articles/PMC10628459/>

Works cited

1. Synthetic Biology Market Expected to Surpass USD 74.7 Billion by 2031 Amid Rapid Advancements in Biotechnology - TMR, accessed October 12, 2025, <https://www.pharmiweb.com/press-release/2024-12-11/synthetic-biology-market-expected-to-surpass-usd-747-billion-by-2031-amid-rapid-advancements-in-biotechnology-tmr>
2. Synthetic Biology Market: Innovations Driving the Next Biotech Revolution, accessed October 12, 2025, <https://www.marketsandmarkets.com/ResearchInsight/synthetic-biology-market-regional-insights.asp>
3. Future Trends in Synthetic Biology—A Report - PMC, accessed October 12, 2025,

- <https://pmc.ncbi.nlm.nih.gov/articles/PMC6692427/>
4. 3 Promising Genomics & Synthetic Biology Stocks in Spotlight in 2025 - Nasdaq, accessed October 12, 2025, <https://www.nasdaq.com/articles/3-promising-genomics-synthetic-biology-stocks-spotlight-2025>
 5. Synthetic Biology Global Market Report 2024, Featuring Profiles of Market Leaders Ginkgo Bioworks, Amyris, Twist Bioscience, Codexis and Thermo Fisher Scientific - ResearchAndMarkets.com, accessed October 12, 2025, <https://crisprmedicineneews.com/press-release-service/card/synthetic-biology-global-market-report-2024-featuring-profiles-of-market-leaders-ginkgo-bioworks-a/>
 6. accessed October 12, 2025, <https://www.marketsandmarkets.com/ResearchInsight/synthetic-biology-market-regional-insights.asp#:~:text=Synthetic%20Biology%20Market%3A%20Innovations%20Driving%20the%20Next%20Biotech%20Revolution,-DOWNLOAD%20PDF&text=The%20global%20synthetic%20biology%20market,US%2431.52%20billion%20by%202029.>
 7. Synthetic Biology Market Forecast: \$61.6 Billion by 2029, Growing at 26.1% CAGR, accessed October 12, 2025, <https://www.bccresearch.com/pressroom/bio/synthetic-biology-market>
 8. accessed October 12, 2025, https://www.researchgate.net/post/What_is_the_difference_between_genetic_engineering_and_synthetic_biology#:~:text=The%20term%20%22Synthetic%20biology%22%20refers,of%20methods%20for%20designing%20and
 9. Future trends in synthetic biology in Asia - PMC - PubMed Central, accessed October 12, 2025, <https://pmc.ncbi.nlm.nih.gov/articles/PMC9744534/>
 10. Twist Bioscience Technology | Silicon-Based Gene Synthesis, accessed October 12, 2025, <https://www.twistbioscience.com/technology>
 11. High Quality Gene Synthesis - Twist Bioscience, accessed October 12, 2025, <https://www.twistbioscience.com/products/genes/gene-synthesis>
 12. A Guide in Synthetic Biology: Designing Genetic Circuits and Their ..., accessed October 12, 2025, <https://www.mdpi.com/2674-0583/3/3/11>
 13. Applications of Synthetic Biology in Food Industry and Agriculture ..., accessed October 12, 2025, <https://www.genscript.com/applications-of-synthetic-biology-in-food-industry-and-agriculture.html>
 14. Base Editing Applications | Beam Therapeutics, accessed October 12, 2025, <https://beamtx.com/science/base-editing-applications/>
 15. Base Editing - Beam Therapeutics, accessed October 12, 2025, <https://beamtx.com/science/base-editing/>
 16. CRISPR Therapeutics: Home, accessed October 12, 2025, <https://crisprtx.com/>
 17. Synthetic biology - Wikipedia, accessed October 12, 2025, https://en.wikipedia.org/wiki/Synthetic_biology
 18. Synthetic Biology Applications: Medical, Industrial, & More - Hudson Robotics, accessed October 12, 2025,

<https://hudsonlabautomation.com/synthetic-biology-applications-medical-industrial-and-more/>

19. Science & Tech Spotlight: Synthetic Biology | U.S. GAO, accessed October 12, 2025, <https://www.gao.gov/products/gao-23-106648>
20. SYNTHETIC BIOLOGY: APPLICATIONS COME OF AGE - NCBI, accessed October 12, 2025, <https://www.ncbi.nlm.nih.gov/books/NBK84446/>
21. About | Ginkgo Bioworks, accessed October 12, 2025, <https://www.ginkgo.bio/about>
22. Innovation at Scale: Ginkgo Bioworks' Approach to Revolutionizing Industries - ETF Trends, accessed October 12, 2025, <https://www.etftrends.com/disruptive-technology-channel/innovation-scale-ginkgo-bioworks-approach-revolutionizing-industries/>
23. Sojitz Corporation and Ginkgo Bioworks Announce Plans to Use Synthetic Biology R&D Services to Accelerate Sustainable Manufacturing in Japan | News Room, accessed October 12, 2025, <https://www.sojitz.com/en/news/article/topics-20240515.html>
24. Twist Bioscience and Ginkgo Bioworks Revise Collaboration, accessed October 12, 2025, <https://investors.twistbioscience.com/news-releases/news-release-details/twist-bioscience-and-ginkgo-bioworks-revise-collaboration>
25. CRISPR Therapeutics and Sirius Therapeutics Announce Multi-Target Collaboration to Develop Novel siRNA Therapies, accessed October 12, 2025, <https://crisprtx.com/about-us/press-releases-and-presentations/crispr-therapeutics-and-sirius-therapeutics-announce-multi-target-collaboration-to-develop-novel-sirna-therapies>
26. Partnerships - CRISPR Therapeutics, accessed October 12, 2025, <https://crisprtx.com/about-us/partnerships>
27. Beam Therapeutics: Breaking new ground to advance science with the potential to change lives, accessed October 12, 2025, <https://beamtx.com/>
28. Our ScienceThe future of gene editing is now - Beam Therapeutics, accessed October 12, 2025, <https://beamtx.com/science/>
29. Amyris, Inc., et al. - Stretto, accessed October 12, 2025, <https://cases.stretto.com/amyris/>
30. AMYRIS ANNOUNCES OPERATIONAL AND FINANCIAL RESTRUCTURING TO ADVANCE STRATEGIC TRANSFORMATION - PR Newswire, accessed October 12, 2025, <https://www.prnewswire.com/news-releases/amyris-announces-operational-and-financial-restructuring-to-advance-strategic-transformation-301897438.html>
31. Safety risks and ethical governance of biomedical applications of ..., accessed October 12, 2025, <https://pmc.ncbi.nlm.nih.gov/articles/PMC10628459/>
32. Ginkgo Makes Biology Easier to Engineer and Scales Cost Efficiently Using AWS Batch | Ginkgo Bioworks Case Study, accessed October 12, 2025, <https://aws.amazon.com/solutions/case-studies/ginkgo-bioworks-case-study/>
33. accessed October 12, 2025, <https://www.twistbioscience.com/products/genes/gene-synthesis#:~:text=Produc>

[t%20Sheet,-Clonal%20Genes%20Product&text=Twist%20Bioscience%20is%20transforming%20gene,time%20and%20price%20per%20base.](#)

34. Amyris rebuilds Post-Bankruptcy - Green Chemicals Blog, accessed October 12, 2025, <https://greenchemicalsblog.com/amyris-rebuilds-post-bankruptcy/>