

## A Brief Introduction to Synthetic Biology

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*In November 2022, Senator Mark Warner (D-VA) suggested that Congress ensure U.S. competitiveness in an emerging sector: synthetic biology.<sup>1</sup> Synthetic biology involves changing the genetic material of organisms for manufacturing applications. Analysts expect significant growth in the synthetic biology industry across the globe, with North America, Europe, and the Asia-Pacific as the largest regional players. The technology is already used in a variety of industries and there is ongoing research to use synthetic biology to produce better, cheaper, and greener products. As this technology advances, it is likely that scientists and businesses will discover more uses for synthetic biology. This EBOT introduces synthetic biology and its current uses and provides a brief overview of the global synthetic biology market.*

**What is synthetic biology?** Synthetic biology is an application of biotechnology that focuses on designing and applying biological processes to innovate manufacturing processes. It involves sequencing, editing, and synthesizing the genetic material of organisms for engineering applications across various industries. The technology has been applied in the production of chemicals, materials, medicines and therapeutics, fuels, agriculture, and even complex circuits.<sup>2</sup> Examples of products made with synthetic biology include [cell-cultured meat](#), pollutant-cleaning microorganisms, and antioxidant-producing rice.

Although synthetic biology may sound like science-fiction, the technology is over 20 years old. Despite promising research advancements and enthusiasm in the scientific community, the emerging technology suffered from high costs until approximately 2011. The tides changed when scientific advancements in printing oligonucleotides—the building blocks of DNA—significantly reduced the costs of gene synthesis. This powered research breakthroughs, including the development of the CRISPR/Cas system, which allows researchers to splice, insert, and edit the genome of living cells.<sup>3</sup> This research catapulted synthetic biology into a commercially viable industry. Recently, some research institutions have established biofoundries<sup>4</sup> to promote the use of synthetic biology at a commercial scale by reducing the cost of prototyping products through a combination of automation and artificial intelligence.<sup>5</sup>

**How is synthetic biology used today?** Synthetic biology is behind the development of the mRNA COVID-19 vaccines, which are the first vaccines to use synthetic biology at such a large scale. However, synthetic biology is not limited to vaccine development. Synthetic biology has been used to treat cancer and facilitate bone and tissue regeneration. It has also been used to convert waste to biofuels, manufacture eco-friendly plastics, mine metals using bioleaching, and produce luxury handbags with mycelium leather.

Analysts predict that applications of synthetic biology can also help solve supply chain issues. For example, plastics made with synthetic biology do not use petroleum, which reduces geopolitical risk. Food made with synthetic biology allows for small-scale, local production,<sup>6</sup> which reduces supply chain vulnerabilities. Similarly, producing fabrics at a small scale can facilitate nearshoring in the apparel industry.<sup>7</sup>

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<sup>1</sup> Information Technology & Innovation Foundation, "[How Updating a Century-Old Trade Law Could Limit](#)," November 28, 2022.

<sup>2</sup> [Report to Congress of the U.S.-China Economic and Security Review Commission](#), November 2021.

<sup>3</sup> The Jackson Laboratory, "[What Is CRISPR](#)," accessed November 30, 2022.

<sup>4</sup> Biofoundries are labs where engineers develop cells to biosynthesize molecules with a variety of applications.

<sup>5</sup> Hillson et al., "[Building a Global Alliance of Biofoundries](#)," December 2019.

<sup>6</sup> Al-Khairi et al., "[Closing the Gap between Bio-Based and Petroleum-Based Plastic](#)," November 23, 2022.

<sup>7</sup> Bryan, "[How Synthetic Biology Can Help Fix the Supply Chain Crisis](#)," April 19, 2022.

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**What does the synthetic biology market look like?** According to market forecasts, the synthetic biology market will grow at a 26.5 percent compound annual growth rate (CAGR) between 2021 and 2026. Growth factors for the industry include falling production costs, rising R&D funding, and advancements in genome synthesis. Because synthetic biology can reduce production waste, clean pollutants, and operate on fewer inputs than some traditional manufacturing, analysts project that synthetic biology will grow alongside demand for sustainable products. This growth has attracted the attention of investors. During the first quarter of 2022, synthetic biology startups received \$4.6 billion of investment, more than four times higher than the first quarter of 2020. This investor enthusiasm may be attributed to the development of the mRNA COVID-19 vaccines, which helped bring synthetic biology into the mainstream.

North America has the largest market share, at 41.1 percent of global revenue in 2021, with the United States as the global leader. As of 2020, the five largest publicly traded and the five largest privately held synthetic biology companies by revenue are headquartered in the United States,<sup>8</sup> with most of the industry located in Boston and San Francisco. These companies specialize in health and beauty, pharmaceuticals, DNA data storage, food, and bioenergy. U.S. firms attract the majority of venture capital investment, at \$1.1 billion during the second quarter of 2019; the rest of the world attracted \$147 million during the same period. In addition to private funding, synthetic biology also receives government funding, primarily from the U.S. Department of Defense.<sup>9</sup>

Europe has the second-largest synthetic biology market share, but the Asia-Pacific region has the fastest-growing market. Drivers of this growth are public and private investment, including academia-industry collaborations and state-sponsored research programs, particularly in China.<sup>10</sup> The Chinese government has invested over \$100 billion in life sciences, established two synthetic biology research centers, and subsidizes existing synthetic biology companies. Analysts forecast that China's synthetic biology market will grow with a CAGR of 32.5 percent between 2020 and 2027, outpacing the global average.<sup>11</sup>

**What challenges are the industry facing?** Globally, impediments to industry growth include scaling biological production processes to an industrial level, consumer acceptance of engineered products, and biosecurity concerns, particularly as regulators flag concerns about the ethics of redesigning organisms and the potential to weaponize infectious agents. U.S. companies also face competition from Chinese companies, which can often deliver cheaper, subsidized products and have been active in acquisitions. Despite these challenges, synthetic biology has the potential to revolutionize countless industries.

Sources: Candelon et al., [Synthetic Biology Is About to Disrupt Your Industry](#), February 10, 2022; GlobeNewswire, [Synthetic Biology Market Is Projected to Reach \\$30.7 Billion](#), October 12, 2022; Isaacs-Thomas, [The Powerful Technology behind the Pfizer and Moderna Vaccines](#), April 2, 2021; Kirk, [A Different Culture Shaping Synthetic Biology in Europe](#), January 7, 2020; Meng and Ellis, [The Second Decade of Synthetic Biology](#), October 2020; National Human Genome Research Institute, [Synthetic Biology](#), August 14, 2019; Philippidis, [Top 10 Synthetic Biology Companies](#), July 2, 2021; [Synthetic Biology Market Size, Share & Trends Analysis Report](#), August 2022.

<sup>8</sup> Mikulic, [Revenue of Leading Public Synthetic Biology Companies](#), April 1, 2022.

<sup>9</sup> NSF - National Science Foundation, [SBWG Agency Funding Opportunities](#), accessed December 16, 2022; Kuiken, [U.S. Trends in Synthetic Biology Research Funding](#), September 2015.

<sup>10</sup> The Chinese government has identified synthetic biology as a field of strategic interest, believing that synthetic biology will help address China's issues of food security and the health needs of its aging population.

<sup>11</sup> Research and Markets, [Synthetic Biology: Global Strategic Business Report](#), October 2022.

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