

Europe's Bio Revolution: Biological innovations for complex problems

Advances in biological science could help the world overcome its most pressing challenges in health and sustainability. Europe's Bio Revolution could translate scientific strengths into impact.

by Matthias Evers, Antonia Stein-Asmussen, Nicole Szlezak, and Alexandra Zemp

Contents

04

Executive summary

05

Europe has strengths that could make it a leading player in the Bio Revolution, but it risks falling behind

12

Europe is at risk of missing the full potential of the Bio Revolution

16

The Bio Revolution can make a significant impact on health and sustainability challenges, but Europe needs to do more

Executive summary

Europe—and the world—faces major challenges, from health threats to climate risk. Advances in biological science can be part of the solution, but Europe needs new impetus to translate its strong science base into a broader application of biological solutions to these complex and difficult issues. One way to breathe new life into Europe's biological-innovation capacity and capabilities is to establish goals for improving citizens' health and mitigating climate risk and then to ensure that Europe's Bio Revolution delivers on those goals. In other words, Europe could pivot to a demand-led rather than supply-led view, making mission-led innovation a core strategy for meeting these challenges.

A Bio Revolution is under way. Fueled by the confluence of progress and innovation in biological sciences and technology, this movement has the potential to help the world overcome its biggest challenges, from health to climate change. We have already seen biological innovation—coupled with powerful computing and AI capabilities—deliver effective COVID-19 vaccines at an unprecedented speed. There is no doubt that biology is one of the keys to not only enhancing health but also tackling climate change.

Europe has considerable scientific strengths, but it has not been wholly effective in translating that capacity into innovation at scale. If Europe were to turn its formidable science base into true impact, the average 65-year-old in 2040 could be as healthy as a 55-year-old today.¹ Furthermore, the European Green Deal would become a reality. Biology-based scientific innovation and commercialization should be an integral part of Europe's strategy to achieve the full potential of the Bio Revolution.

In this article, we describe the foundations and progress of the Bio Revolution in Europe, looking at strengths as well as weaknesses and how they might be overcome to meet some of the most complex challenges facing the region and the world.

¹ *Prioritizing health: A prescription for prosperity*, McKinsey Global Institute, July 2020.

**A Bio Revolution is under way—
fueled by the confluence of
progress and innovation in biological
sciences and technology.**

1 Europe has strengths that could make it a leading player in the Bio Revolution, but it risks falling behind





Europe has a world-class science base with high-quality scientific publishing and an active patent scene. Hundreds of companies are engaged in aspects of the Bio Revolution, including health and life, agricultural, and earth science as well as multiple paths to innovation and financing (see sidebar “What is the Bio Revolution?”).

What is the Bio Revolution?

A confluence of advances in biological sciences—which have been in the making for decades—and the accelerating development of computing, automation, AI, and data analysis are fueling a wave of innovation that the McKinsey Global Institute (MGI) has named the Bio Revolution.¹ The Bio Revolution describes a broad landscape of innovation across technologies and domains; others may use the term “synthetic biology” to describe at least part of this revolution. MGI research focuses on advances in four areas: biomolecules, biosystems, biomachine interfaces, and biocomputing (exhibit).

Exhibit

Bio innovation is occurring in four key arenas.

	 Biomolecules	 Biosystems	 Biomachine interfaces	 Biocomputing
Definitions				
Mapping	Cellular processes and functions via measuring intracellular molecules (eg, DNA, RNA, proteins) in the study of omics	Complex biological organizations and processes, as well as interactions between cells	The structure and function of nervous systems of living organisms	Intracellular pathways or networks of cells to return outputs based on specific conditions (for computation)
Engineering ¹	Intracellular molecules (eg, via genome editing)	Cells, tissues, and organs, including stem cell technologies and transplantation	Hybrid systems that connect nervous systems of living organisms to machines	Cells and cellular components for computational processes (storing, retrieving, and processing data)
Examples	Gene therapy for monogenic diseases	Cultured meat grown in a lab	Neuroprosthetics for motor control (implant or external headset) of human or robotic limb	Data storage in strands of DNA

¹Design, de novo synthesis, or modification.
Source: McKinsey Global Institute analysis

What is the Bio Revolution? (continued)

The pace of the Bio Revolution is accelerating. For instance, the annual number of patents in core domains of the Bio Revolution, including artificial enzymes, cell printing, and biocomputing, is rising. The most notable aspect of the revolution is the increase in biosystem patents. For instance, McKinsey analysis found that the number of cell-printing patents increased at a compound annual rate of almost 40 percent, and the number of engineered-bacteria patents increased by about 17 percent between 2015 and 2019. According to Synbiobeta, investment in synthetic-biology companies smashed all previous records in the first quarter of 2021.² Synthetic-biology companies raised about \$4.6 billion in that quarter alone, more than four times the investment in the same quarter a year earlier. Another analysis predicts that the synthetic-biology market will grow by more than 20 percent over the next five years.³

MGI cataloged and analyzed a pipeline of about 400 visible use cases in multiple industries, almost all of which are scientifically feasible today. These applications alone could have a direct, worldwide annual economic impact of \$2 trillion to \$4 trillion over the next ten to 20 years, with more than half of this impact in domains such as agriculture and food, consumer products and services, and materials and energy production. Considering potential knock-on effects, new applications that have yet to emerge, and additional scientific breakthroughs, the full potential could be far larger. To give a sense of the potential scale, as much as 60 percent of the physical inputs to the global economy today that are either biological (wood and animals reared for food) or nonbiological (cement or plastics) could be produced or substituted using biology.

¹ *The Bio Revolution: Innovations transforming economies, societies, and our lives*, McKinsey Global Institute, May 2020.

² Stephanie Wisner, "Q1 shatters previous synthetic biology investment record - Signals projected 2021 investment of up to \$36 billion," Synbiobeta, accessed October 2022.

³ "Synthetic biology market global outlook and forecast 2022-2027: Significant rise in investments fueling sector growth," Business Wire, August 5, 2022.

Europe's science base is strong

Europe is home to 42 percent of the world's top 100 universities for life sciences and 31 percent of the top 100 for computer science, according to *Times Higher Education's* World University Rankings 2022.²

Europe also leads on high-quality publications. In 2020, the latest year for which figures are available, the CWTS Leiden ranking puts Europe ahead on "top," or well-regarded, publications covering health, agriculture, and industrial biotech, with the United States and China second and third.³ On this measure, Europe pulled further ahead of the United States between 2014 and 2020, while China substantially narrowed the gap (Exhibit 1).

Europe is performing well on patents and incremental innovation overall. According to McKinsey analysis based on the World Intellectual Property Organization's (WIPO) patent data, over the past five years, more than 40,000 health-biotech patents were granted in Europe, compared with about 50,000 in the United States and 39,000 in China. Where there is more incremental innovation, Europe outperforms the United States on Bio Revolution-related technologies, with 20,000 in food-related technology, 30,000 for macromolecular chemistry, and 25,000 for environmental technology. Furthermore, the growth of patent approval in these areas is faster in Europe than in the United States, and China is making significant progress. China leads on environmental technology with 45,000 patents over the past five years and a 5 percent compound annual growth rate, compared with 3 percent in Europe. If we look deeper, however,

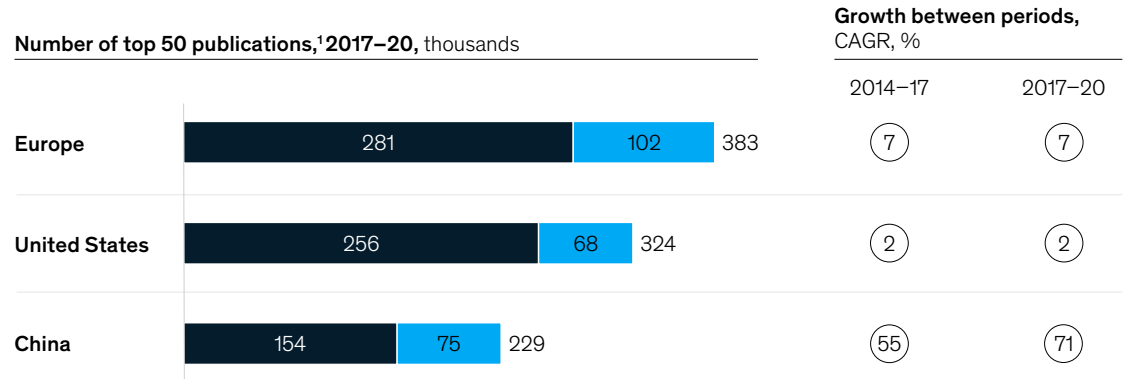
² "World University Rankings 2022 by subject: Life sciences," *Times Higher Education*, accessed October 2022.

³ "CWTS Leiden Ranking 2022," CWTS Leiden Ranking, accessed October 2022.

Exhibit 1

In terms of high-quality publications, Europe is a leader.

■ Health ■ Agriculture and industrial



¹Number of publications in region that, compared with other publications in the same field (biomedical and health science; life and earth science) and year, belong in the top 50% of most frequently cited publications (calculated by summing up all top 50% publications of several universities; 1225 universities were considered worldwide).
Source: CWTS Leiden Ranking 2022

McKinsey & Company

at critical Bio Revolution technologies such as cell printing or engineered bacteria, our analysis using Spark Beyond data finds that US-based players hold nine out of the ten top spots for patent holders.

China is making up ground in terms of individual research institutions. Indeed, the Chinese Academy of Sciences (CAS) ranks first on the Nature Index ahead of Harvard University in the United States and the Max Planck Society in Germany.⁴ Furthermore, China has six of the top ten “young” universities—less than 50 years old—according to the World Economic Forum.⁵

Thousands of European companies are active in areas of the Bio Revolution

While Europe’s science base is strong, the number of companies identified as active in the Bio Revolution is significantly lower in Europe than in the United States—about 4,500 versus 8,000, respectively. However, there are considerable connections and convergences among cross-functional clusters, suggesting that Europe has a developing ecosystem that can support further progress in the Bio Revolution.

We identified a broad set of about 4,500 companies in Europe using a keyword search for technologies and products associated with the Bio Revolution, including synthetic biology, biological engineering, “omics” sciences, genome editing, biocomputing, and cell engineering. Some of the companies we identified may not qualify as pure Bio Revolution players, but all are associated with the ecosystem. The companies represent about 100 primary industries, including agriculture, chemicals and gases, food, energy, healthcare, and pharmaceuticals.

⁴ Gemma Conroy and Benjamin Plackett, “Nature Index Annual Tables 2022: China’s research spending pays off,” *Nature*, June 16, 2022.

⁵ Phil Baty, “Asian universities are on the rise. This is what it means for the rest of the world,” World Economic Forum, July 8, 2021.

We then used natural-language processing and similar analytics to group those companies into 18 natural-language clusters that range from therapeutics to biomaterials, biofuels, and crop-related activities. The clusters also cover some traditional industries, including pharmaceutical services and drug development and discovery (Exhibit 2), and several cross-functional clusters that are core to the Bio Revolution landscape (see sidebar “Europe’s Bio Revolution: 18 natural-language clusters”).

Europe lacks the larger platform players and bio-first companies that are attracting considerable investment in the United States, such as Ginkgo, Sana Biotechnology, and Zymergen.⁶ Europe is home to some leading players, including BioNTech and Novozymes, but there is no bio-first company headquartered in Europe.

Biotech funding is increasing in Europe but not as fast as in the United States

There was a significant increase in funding for biotech and Bio Revolution–adjacent companies from 2019 to 2021. In health biotech, for example, average venture capital (VC) funding for EU biotech companies grew by 42 percent between 2019 and 2021.⁷ However, total funding remains materially below levels in the United States or China, and the gap is increasing.

Looking at the broader Bio Revolution landscape, funding is increasing in Europe, particularly in healthcare, but the volume of funding is still significantly smaller than in the United States and is growing less quickly. Overall, the total volume of funding is four times higher in the United States than in Europe. Of the 4,500 companies identified in Europe, about 35 percent have received VC, private-equity, or IPO funding over the past five years, compared with about 45 percent in the United States, according to McKinsey research.

According to McKinsey research, the absolute number of companies that have received funding since 2015 in the United States (3,577) is more than double that in Europe (1,558) as of June 2021. Moreover, the average capital that each company raised was more than 1.5 times higher in the United States (\$65 million) than in Europe (\$40 million). Looking at the trajectory of growth, Europe may be falling further behind. While funding between 2015 and 2020 grew at a solid compound annual growth rate of 9 percent in Europe, it grew at a rate of 26 percent in the United States.

For cross-functional clusters, specifically bioinformatics, biomaterials, cell-based clusters, gene-based clusters, genomic analysis, molecular diagnostics, and synthetic biology, investment volume was more than four times higher in the United States (\$52 million) than in Europe (\$14 million) from 2018 to 2020. This is despite the fact that the volume of such investment doubled in Europe from 2015 to 2017. In the case of emerging smaller clusters such as plant-based meat and microbiomes, the difference in investment volume between the United States and Europe is even larger (more than five times investment volume versus more than ten times, respectively). The only cluster in which funding was comparable from 2018 to 2020 was microalgae.

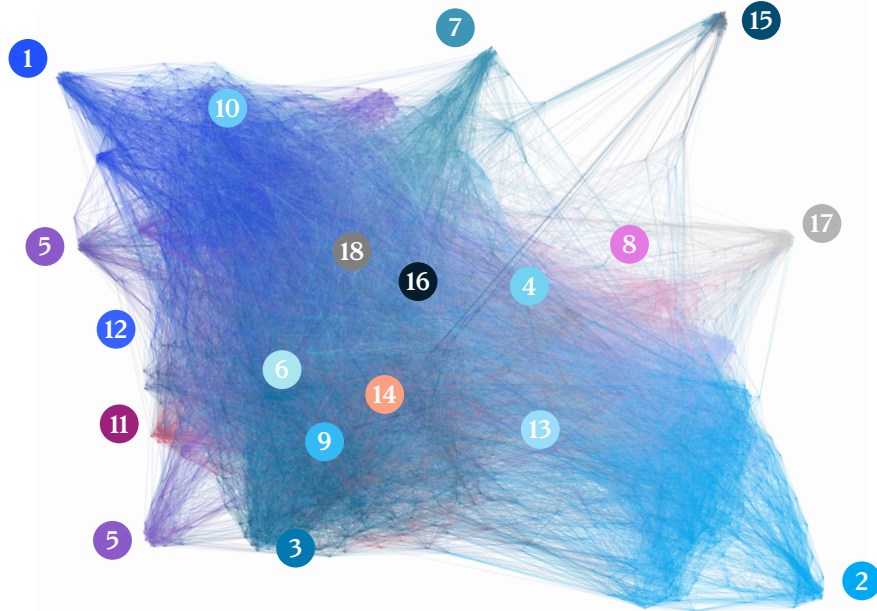
⁶ In September 2022, Ginkgo announced the completed acquisition of Zymergen.

⁷ For more, see Ivana Kolic, Joseph Lydon, Lisbeth Van Ruijssevelt, and Alexandra Zemp, “How the European biotech sector can navigate turbulent times,” McKinsey, October 11, 2022.

Exhibit 2

In Europe’s Bio Revolution, health-related companies account for about half of the 4,500 companies in the 18 natural-language clusters.

Europe Bio Revolution ecosystem, n = 4,487 companies



Ecosystem of companies based on similar company descriptions

Cluster name	Share of total, %	Cluster name	Share of total, %
1 Therapeutics and pharmaceuticals	15	10 Gene-based	4
2 Biofuels and renewable energy	14	11 Genomic analysis (health and nonhealth)	3
3 Bioinformatics	9	12 Pharmaceutical manufacturing	2
4 Biomaterials and biochemicals	9	13 Crop-related technology	2
5 Pharmaceutical services, drug development, and drug discovery	9	14 Biosensor and medical devices	2
6 Molecular diagnostics	9	15 Biotechnology services	2
7 Cell-based	8	16 Microbiome	2
8 Microalgae	5	17 Plant-based meat and food	1
9 Synthetic biology	5	18 Fertility and prenatal screening	1

Note: Figures may not sum to 100%, because of rounding.
Source: McKinsey Growth Analytics; McKinsey Strategy & Corporate Finance Insights

McKinsey & Company

Europe’s Bio Revolution: 18 natural-language clusters

Natural-language clusters fall into three categories: health; industry, agriculture, and food; and cross-functional (exhibit).

Health. More than half of companies in the Bio Revolution ecosystem in Europe are active in healthcare or pharmaceuticals, which are in seven clusters: therapeutics and pharmaceuticals; pharmaceutical services, drug development, and drug discovery; molecular diagnostics; pharmaceutical manufacturing; biosensors and medical devices; biotechnology services; and fertility and prenatal screening.

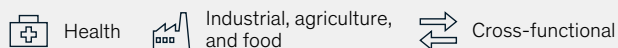
Industry, agriculture, and food. Three clusters are related to industry, agriculture, and food: biofuels and renewable energy, crop-related technology, and plant-based meat and food.

Cross-functional. Seven clusters are cross-functional and more closely linked to the Bio Revolution. They cover bioinformatics, biomaterials and biochemicals, cell-based, and synthetic biology, among others. These cross-functional clusters are strongly interlinked with other clusters, such as therapeutics, biofuels, and renewable energy. Other clusters span several primary industries. For example, biomaterials are relevant in about 40 primary industries from agriculture to healthcare, and microalgae is relevant in about 30 primary industries. This demonstrates that technologies can be used across industries.

Looking at individual clusters, the largest share of European companies (15 percent) is in the therapeutics and pharmaceuticals cluster. The second-largest cluster, with 14 percent of European companies, is in biofuels and renewable energy, and the third-largest cluster is biomaterials and biochemicals, accounting for 9 percent of European companies in our analysis. In the United States, the largest cluster is also therapeutics and pharmaceuticals with 20 percent of companies, followed by biofuels and renewable energy with 8 percent.

Exhibit

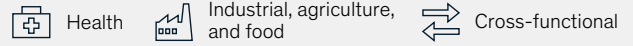
The European Bio Revolution landscape consists of 18 natural-language clusters.



Cluster	Description	Category
Therapeutics and pharmaceuticals	Companies engaged in developing and commercializing therapeutics products or biological solutions for many diseases, oncology, body pain, and antibiotic resistance, among others	
Biofuels and renewable energy	Companies engaged in producing bio-fuels and renewable energy by different technologies such as bio-based residue, organic waste, carbon emissions, and animal fat	
Bioinformatics	Developers of applications, platforms, or software to help the biotechnology industry across many segments, including leveraging AI or machine learning (recognizing viral vectors, sequencing data, etc)	
Biomaterials and biochemicals	Manufacturers of biomaterials to develop novel types of materials or to improve the quality and production of materials across industries, such as medical devices, building materials, cosmetics, and textiles	
Pharmaceutical services, drug development, and drug discovery	Companies engaged in developing and discovering drugs, including services such as drug delivery systems, laboratory research, consulting, and regulatory studies	
Molecular diagnostics	Companies specialized in the development of molecular diagnostics and associated services for many medical diseases, oncology, and other fields	

Exhibit

The European Bio Revolution landscape consists of 18 natural-language clusters. (continued)



Cluster	Description	Category
Cell-based	Companies engaged in research and production of cell-based products such as stem cells, cell therapy, and other specialized products and services such as cell expansion monitoring services and cell modification	
Microalgae	Companies specialized in producing algae or algae-based products for different industries or segments such as biotechnology, building products, nutrition, cosmetics, and textiles	
Synthetic biology	Companies engaged in providing services and products in the synthetic-biology segment, such as DNA synthesis, genomic systems, protein design, and biological engineering, often leveraging AI or machine learning	
Gene-based	Providers and developers of gene therapy and services such as genetic-vaccination delivery, genomic-sequencing improvement, and novel-vector improvement for treating many diseases	
Genomic analysis (health and nonhealth)	Companies engaged in providing integrative solutions for analysis and interpretation of data delivered from genomics technologies, such as genomic data, genomic test, gene expression, and DNA sequencing	
Pharmaceutical manufacturing	Development and manufacture of pharmaceutical ingredients, including advanced intermediates, functional specialty ingredients commonly used in biochemicals, diagnostic, and cosmetics	
Crop-related technology	Providers of crop improvement and protection through agricultural biotechnology products and services, such as genome-edited crops, genetically-engineered crops, biopesticides, and biostimulants	
Biosensor and medical devices	Manufacturers and providers of biosensors technology and medical devices for diagnostics, DNA testing, food traceability, target druggability, SAR ¹ analysis, screening infectious diseases, and others	
Biotechnology services	Companies engaged in associated services for the biotechnology industry such as drug development acceleration, specialized research, personalized medicines, and targeted therapies	
Microbiome	Companies focused in microbiome solutions, such as nourishing the human microbiome, microbiome therapeutics, fortifying the microbiome, microbiome-derived metabolites, and microbiome sequencing	
Plant-based meat and food	Producers of plant-based meat products, such as proteins, protein ingredients, cell-based meat, and non-GMO products, as well as food services certification providers	
Fertility and prenatal screening	Companies focused on infertility treatment including in-vitro diagnostics, infertility procedures, embryonic stem cells, fetal genetic analysis, and pregnancy health testing	

¹Structure–activity relationship.

2

Europe is at risk of missing the full potential of the Bio Revolution

Despite its many strengths, Europe has work to do before it can assume a leading position in the Bio Revolution. Contributions to this effort need to come from not only national governments but also the supranational institutions of the European Union, given that the market is fragmented. And policy leaders need to work together with companies and with business leaders to unleash a new spirit of risk-taking and entrepreneurship—an area in which Europe has some weakness.

The European market is fragmented because it comprises many smaller national markets with different languages and regulations as well as barriers.⁸ This hinders the ability of Europe's Bio Revolution players to scale up. In healthcare, notably, differences in reimbursement and regulation lead to fragmentation and a smaller home market value. Public and private capital is rising for biological innovation, as we have noted, but the fact remains that Europe's investor base is still dispersed.⁹ Europe-based funds (particularly late-stage funds) have grown significantly since 2010 and are achieving net internal rates of return on late-stage investments of 15 percent, compared with 13 percent in the United States. However, the United States still has more large-scale funds with 22 funds of more than \$1 billion, compared with only one of this size in Europe.

Another hurdle to the progress of the Bio Revolution in Europe is the absence of a risk-taking, entrepreneurial culture. Although Europe has excellent universities and has made significant advances in developing and attracting biotech talent in recent years, formation of new companies in the region has not increased. In the past six years, Europe accounted for only 24 percent of the world's new biotech companies in 2018 to 2020, compared with 65 percent for the United States and 12 percent for China.¹⁰ For comparison, the shares of Europe and the United States were down slightly from 25 percent and 67 percent, respectively, in 2015 to 2017 while China's share was up from 8 percent. Global Entrepreneurship Monitor data for 2021 indicated that Europe still lags behind on the necessary capabilities and desire to form new companies, although it has started to close the gap since the 2018 report.¹¹ In the five largest European economies (France, Germany, Italy, Spain, and the United Kingdom), only 45 percent of adults see good opportunities to start a firm, compared with 65 percent in the United States, and only 45 percent believe they have the required skill and knowledge to start a business versus 65 percent in the United States. Overall, 16.5 percent of US adults are entrepreneurs, but only 7.5 percent of adults from the European countries listed above are.¹²

⁸ "Can European biotechs achieve greater sale in a fragmented landscape?," McKinsey, June 29, 2021.

⁹ *Innovation hotspots to drive the next act in Europe*, a joint report from Bio€quity Europe and McKinsey, May 17, 2021.

¹⁰ *Ibid.*

¹¹ "Entrepreneurial behaviour and attitudes," Global Entrepreneurship Monitor, accessed October 2022.

¹² *Ibid.*

Beyond these broad factors that may be limiting Europe's potential as a leading force in the Bio Revolution despite its strong science base, Europe has four areas of relative weakness.¹³ In this section, we look at these four areas and suggest some potential solutions.

- **Accelerating speed on the road from research to commercialization.** As we have outlined, the translation of scientific research into commercial opportunities in Europe has tended to be slower and lower than in other major economies. This is in part because Europe has a relatively small base of specialized VC funds, and those that are active tend to be smaller and more risk averse than those in the United States and other countries. Academics in Europe focus even more on research than their counterparts in other geographies do, and they appear to have less business acumen. Furthermore, funding for research and applications for grants are in many cases independent of how that research might be applied; this means that the research is free (or freer) of bias, but it also leads to a gap between research and application.

To bridge this gap, most top European research institutes and universities have established tech transfer offices (TTOs) and technology licensing offices (TLOs), but these initiatives will take time to make an impact. In addition, according to a study by the European Patent Office, TTOs and TLOs in Europe tend to be small: 56 percent of them have ten or fewer employees, with only one to three people dealing with patent commercialization.¹⁴ In comparison, MIT's TLO includes about 50 members. Moreover, there are incubators at most universities and institutions, as well as private- and public-support programs; one example is the Catapult initiative in the United Kingdom.

There are several steps that could be taken to address these issues within the next five to ten years, such as addressing risk aversion and developing capabilities, incentives, and structural support to overcome the disconnect between research and the market. More investment in cross-cutting capabilities in science and business would be useful, including improving business curriculums for scientists in universities, providing more funding for high-caliber research, ensuring that high-skill immigration pathways are in place to attract top talent, increasing funding of TTOs and TLOs, and even setting up an industry platform that can validate the business potential of the most promising research.

- **Moving toward collaboration and convergence.** The Bio Revolution is not about pure biology—it's about the confluence of biology and other disciplines, notably computing, AI, and data analytics. Most fields of science are becoming more cross-disciplinary—the term “revolution of convergence” has been used to describe this.¹⁵ Europe has considerable strength in traditional industries such as chemicals and the life sciences but lags behind the United States and other countries on digitalization and platform-based business models.¹⁶ Fragmentation again plays a part: Europe does not have concentrated “super hubs” like Silicon Valley or the Boston area, and it therefore is not as effective in bringing capabilities, investors, and platforms together. Nevertheless, Europe is leading the way on emerging ecosystems: 37 percent of the top 100 start-up ecosystems are located in the region, according to a 2022 Startup Genome report.¹⁷ Amsterdam and Stockholm's start-up ecosystems are in the top 25 globally, with strong footprints in cleantech, life sciences, agricultural technology, and plant-based meat.¹⁸

¹³ For more, see “Europe's start-up ecosystem: Heating up, but still facing challenges,” McKinsey, October 11, 2020; and *Innovation hotspots to drive the next act in Europe*, May 17, 2021.

¹⁴ “New EPO study: European patents preferred tool for the commercialisation of inventions developed by European universities and public research organisations,” European Patent Office, November 24, 2020.

¹⁵ “What is convergence?,” Convergence Revolution, accessed October 2022.

¹⁶ *Digital Europe: Pushing the frontier, capturing the benefits*, McKinsey Global Institute in collaboration with Digital McKinsey, June 2016.

¹⁷ *The global startup ecosystem report: GESR 2022*, Startup Genome, 2022.

¹⁸ *Ibid.*

In the next five to ten years, Europe should aim to foster bio-innovation and tech ecosystems that enable convergence, collaboration, and innovative business models. One ecosystem model is shaped like a barbell, with many small, science-based companies balanced by a few large incumbents to drive the commercialization of new biological technologies. Partnerships and collaborations between science players and tech players will be a vital part of effective convergence, as will biology-first technology platforms. Interdisciplinary teams need to be developed, and Europe could even consider establishing cross-disciplinary networks across research and academia to foster the confluence of disciplines. European institutions and policy makers could enable convergence by encouraging cross-regional collaboration and knowledge sharing; one useful step would be to create accessible pan-European scientific databases.

- **Striking the right balance between risk mitigation and innovation.** Europe's policy makers tend to take a safety-first view on many dimensions, and the progress of the Bio Revolution faces regulatory barriers. The Bio Revolution doubtless has risks—some of which are serious—that demand a conscientious regulatory response (see sidebar “The risks of the Bio Revolution”). In industrial and agricultural biotech, regulatory uncertainty is constraining the viability of some innovation; for example, 19 of the 27 member states of the European Union have partially or fully banned the cultivation and sale of genetically engineered food products.¹⁹ Moreover, Europe has taken a robust stance on data privacy, notably through its General Data Protection Regulation (GDPR). The European Union tightly guards “omics” science data with special provisions under its GDPR, and healthcare-related data are less broadly available through regional databases there than in the United States. Yet biological and genomic data are critical to tap into the full value of the Bio Revolution.

Europe needs to strike the right balance to capture the full potential of biological innovation. In the next five to ten years, the region should assess the existing balance and where it should be. Even while mitigating risk through regulation—perhaps lighter-touch regulation—EU governments and institutions could focus on enabling innovation; setting a strategic direction, as China, the United Kingdom, and the United States have done (see the final section of this paper for more detail); and providing effective incentives, such as what happened in the cases of biosimilars (biological medicines that are very similar to another already approved biological medicine) and digital health applications. The European Union was the first region in the world to define a policy and legal framework for the approval of biosimilar medicines, and its first biosimilar was approved in 2006, nearly a decade before the first one was approved in the United States. As of September 2022, 88 biosimilars had been approved in Europe, compared with 39 in the United States. Germany was the first country to allow prescription and reimbursement for digital health applications—*Digitale Gesundheitsanwendungen (DiGA)*—under a regulation that came into effect in December 2019. This has boosted digitalization and innovation in the German health system. As of August 2022, almost 150 companies from Germany and across the world had applied for this new pathway.²⁰

Tax breaks or innovation programs could encourage risk-taking behavior and create a level playing field with other regions that take a less stringent regulatory approach. For example, direct-to-consumer genetic testing is permissible in the United Kingdom, but not in France and Germany; the European Union is working on a new regulation to address patchy regulation across member states. Finally, information campaigns could encourage public acceptance of new biology-based technologies by highlighting their advantages.

¹⁹ “Several European countries move to rule out GMOs,” European Green Capital, accessed August 2022.

²⁰ “DiGA: Digital health applications,” Federal Institute for Drugs and Medical Devices, accessed August 2022.

The risks of the Bio Revolution

New biological capabilities come with profound and unique risks that need serious, ongoing debate and proactive, rather than reactive, approaches toward mitigation. One risk is that biological systems are self-sustaining, self-replicating, and interconnected, with potentially cascading and long-lasting effects on entire ecosystems or species. Once Pandora's box is opened, we could have little control over what happens next. These tools may be relatively cheap and easy to access, making the potential for misuse considerable. Privacy and consent issues abound because of new forms of biological data. And responding to such challenges through cooperation and coordination may be complicated given competitive and commercial incentives and varying jurisdictional or cultural value systems.

- **Insufficient access to funding.** Funding for biological innovation is increasing in Europe—but not fast enough. Raising large capital sums in IPOs on European stock markets has continued to be difficult. For example, we found that the mean size of European biotech IPOs was four to five times larger on US exchanges than on European exchanges, and 95 percent of European biotech companies listed in the United States are listed on the Nasdaq. Europe could strive to match US and Chinese levels of funding for biotech and other aspects of the Bio Revolution.²¹ Potentially useful initiatives include revisiting valuation and accounting principles to reward investment in intangibles that can enhance innovation, as well as rethinking incentives and regulation for VC funds.²² In a departure from traditional corporate venture funding, which tends to be predominantly an investment vehicle rather than a major source of pipeline innovation, Europe could explore structures of mutual funds to tap into institutional funding and achieve scale. This strategy could build on industry-driven VC approaches, such as those used by the Novartis Venture Fund and Leaps by Bayer. These models seek innovative codevelopment and intellectual-property arrangements that allow larger companies to codevelop novel technologies with some of the world's leading Bio Revolution players. Governments could make efforts to attract investors from outside the home country of the Bio Revolution company. One option could be to create a European Nasdaq spinoff.

²¹ *Innovation hotspots to drive the next act in Europe*, May 17, 2021.

²² "Getting tangible about intangibles: The future of growth and productivity?," McKinsey Global Institute, June 16, 2021.

3

The Bio Revolution can make a significant impact on health and sustainability challenges, but Europe needs to do more

If this revolution reaches its full potential, it could play an important role in tackling two of our most complex, pressing, and difficult problem areas: health and sustainability in an era of increasing climate risk. The question is how to breathe new life into biological innovation in order to meet these challenges.

The shortcomings described, including relatively weak entrepreneurship, difficulties in translating basic science into new value propositions, and scaling new businesses in Europe, are largely on the supply side, and they have proved difficult to address decisively. Some are complex and structural and therefore somewhat intractable.

But the prize of accelerating the Bio Revolution is so significant that it may be worth looking at the problem from a different angle: the demand side. European stakeholders could ask themselves, “Where do we want to be? How do we get there?” The necessary momentum could materialize if stakeholders aired the best ideas about the issues that Europe wants to solve, defined an end goal, and then used that goal to push demand by motivating strategy, policy, and investment. In short, mission-led innovation could be the key to success for Europe’s Bio Revolution.

Mission-led innovation could ensure that advances in biological science—and in other disciplines that are enabling those advances—are fully harnessed to meet broad societal goals in Europe. Famously, landing a human being on the moon is an example of biological innovation that had broader societal impact. Setting a direction for this kind of innovation can unite a range of stakeholders and become a vehicle for collaboration at scale. According to economist Mariana Mazzucato, common missions have the potential “to orchestrate the rich diversity of talent and expertise that today lies mostly fragmented or untapped across Europe.”²³

Some countries have outperformed Europe in capturing the potential of biological innovation by establishing explicit strategies, strategic missions, and dedicated funding that go well beyond healthcare systems. In October 2020, the US Department of Defense announced a substantial funding award to the Bioindustrial Manufacturing and Design Ecosystem (BioMADE), a nonprofit designed to advance bioindustrial manufacturing technologies.²⁴ The Israel Innovation Authority is investing in bioconvergence technologies to ensure that professionals in biology, computer science, mathematics, engineering, and nanoscience work seamlessly together.²⁵ In 2018, the United Kingdom unveiled a national bioeconomy

²³ Mariana Mazzucato, *Mission-oriented research & innovation in the EU: A problem-solving approach to fuel innovation-led growth*, European Commission, Directorate-General for Research and Innovation, February 2018.

²⁴ “DOD approves \$87 million for newest bioindustrial manufacturing innovation institute,” US Department of Defense, October 20, 2020.

²⁵ Brian Blum, “Bioconvergence - The next big thing from Israel,” Israel 21C, October 8, 2020.

strategy.²⁶ In July 2022, the United Kingdom moved one step closer to launching its new Advanced Research and Invention Agency, appointing a chief executive officer and chair.²⁷ China's 13th and 14th five-year plans made biological innovation and biotech a major theme.²⁸

So how big is the prize that could be the mission goal? We look in particular at the potential gains in health and sustainability that the Bio Revolution can deliver.

Health

Previous research from the McKinsey Global Institute (MGI) found that the Bio Revolution could address at least 45 percent of the world's disease burden with science that is conceivable today. Biological innovation related to health is currently the most advanced strand of the Bio Revolution, and it has significant potential to improve the health of Europe's citizens. There is an opportunity to handle future pandemics more effectively, cure diseases or prevent them from developing, and increase life expectancy; as previously noted, MGI research has found that the average 65-year-old in 2040 could be as healthy as a 55-year-old today.²⁹ Beyond improving individual health by shifting some focus from caring for the sick to focusing on preventive health, this strand of the Bio Revolution could have tremendous socioeconomic impact. For instance, it could foster a larger and healthier workforce by expanding the capacity of older people, people with disabilities, and informal caregivers to work, as well as by increasing productivity as the burden of chronic health conditions is reduced.

Bio Revolution can have three large-scale societal impacts:

- **Curing or slowing down progression of diseases.** Cancer is still one of our biggest health challenges. Novel therapies are emerging, such as CAR-T cell therapy, a treatment for solid tumors offered by Novartis and other major pharmaceutical companies. Gene therapies for genetic diseases can now heal previously incurable diseases; one example is Novartis's treatment of spinal muscular atrophy with its drug Zolgensma.³⁰ Another example is GenSight Biologics' use of gene therapy to cure blindness.³¹ CRISPR Therapeutics of Switzerland is using CRISPR technology—which edits genes and reprograms cells—to treat sickle cell anemia and is seeking approval by EU and UK regulators by the end of 2022.³² The microbiome as a driver for disease and a potential target for modulation is currently being evaluated in relation to a number of diseases, including Alzheimer's and inflammatory diseases such as rheumatoid arthritis. In some cases, microbiome approaches are being evaluated to develop therapies as an alternative to antibiotics. For instance, Gedeo Biotech of Sweden aims to develop the first antibiotic-free treatment for bacterial vaginosis.³³

²⁶ *Growing the bioeconomy*, UK Department for Business, Energy & Industrial Strategy, December 5, 2018.

²⁷ "Innovation heavyweights appointed to lead new Advanced Research and Invention Agency," UK Department for Business, Energy & Industrial Strategy, July 19, 2022.

²⁸ Rolf D. Schmid and Xin Xiong, "Biotech in China 2021, at the beginning of the 14th five-year period ('145')," *Applied Microbiology and Biotechnology*, 2021, Number 105.

²⁹ *Prioritizing health*, July 2020.

³⁰ "Novartis announces Nature Medicine publication of Zolgensma data demonstrating age-appropriate milestones when treating children with SMA presymptomatically," Novartis, June 17, 2022.

³¹ "GenSight Biologics reports 5 years' data showing sustained efficacy and safety following one-time treatment with LUMEVOQ®," Business Wire, July 20, 2022.

³² Hannah Kuchler, "Revolutionary Crispr gene editing speeds from lab to treatment room," *Financial Times*, August 19, 2022.

³³ "Gedeo Biotech has completed the recruitment for NEFERTITI clinical trial of pHyph antibiotic-free treatment of bacterial vaginosis," Gedeo Biotech, February 8, 2022.

- **Enabling people to live longer in better health.** Senolytics and regulation of cellular aging are now being used to address the root causes of aging and several diseases. For instance, Numeric Biotech in the Netherlands and Eternans in the United Kingdom are developing senolytic agents for the treatment of senescence-associated diseases and disorders by selectively killing senescent cells. Improved diagnostics and personalized medicine can lead to therapies that react more quickly and are more targeted. One example of this is the use of next-generation sequencing in combination with AI algorithms that can serve as an input for treatment decisions, as in the case of Swiss biotech Sophia Genetics, which is applying this approach in oncology, hereditary cancer, cardiovascular diseases, neurological disorder, metabolism, and rare diseases.³⁴ German company CureVac RMA Printer GmbH is developing mRNA printer technologies to produce customized therapeutic cancer vaccines and other vaccines.³⁵
- **Improving quality of life.** MGI research found that preventing, diagnosing, and treating diseases could have an impact of \$0.5 trillion to \$1.3 trillion over the next ten to 20 years, and the majority of that value could come from the prevention, diagnosis, and treatment of cancer, infectious diseases, and aging-related health damage.³⁶ The development of COVID-19 vaccines is a prominent example of prevention that has saved many lives. Two of the most widely distributed COVID-19 vaccines were developed by scientists in Europe: the Pfizer-BioNTech vaccine and the AstraZeneca vaccine, developed in partnership with Oxford University. An estimated 700,000 global deaths every year result from vector-borne infectious diseases such as malaria. In the past, controlling such diseases by altering the genomes of entire populations was not feasible, but CRISPR technologies are changing this. Robotics, including electroceuticals, connected devices, and prosthetics, are also helping people live healthier lives. For example, Spain's GOGO A is developing mobility robots to help people who have suffered neurological damage.³⁷

Sustainability and climate risk

Sustainability and mitigating climate risk are becoming core priorities for not only policy makers but also many investors and CEOs. MGI's previous research found that the Bio Revolution could reduce annual average manmade greenhouse-gas emissions by 7–9 percent from 2018 emissions levels, even while raising prosperity.³⁸ But biological innovation has many other applications that can help create a collectively more sustainable economy:

- **Reaching net-zero emissions.** Slowing the rise in global temperatures is arguably the largest challenge of our time. The Bio Revolution has huge potential in this area, particularly in reducing CO₂ levels. Replacing meat with plant-based or cell-based alternatives could help to reduce emissions from livestock, which account for 14.5 percent of global CO₂ emissions, according to estimates by the Food and Agriculture Organization of the United Nations. It could also maintain food security because plant- or cell-based protein could be a more sustainable food resource. Biosequestration (taking CO₂ out of the atmosphere) is another promising area. For instance, algae have a CO₂ fixation efficiency that has been estimated to be ten to 50 times higher than that of terrestrial plants, and they are being evaluated as a potential source of renewable energy.³⁹ Another promising area of innovation is carbon capture. For example, in Iceland, the world's largest carbon capture plant, Orca, opened in 2021.⁴⁰

³⁴ For more, see the Sophia Genetics website.

³⁵ Joseph Keenan, "CureVac launches 'RNA printer' subsidiary to provide clients with flexible mRNA manufacturing," *Fierce Pharma*, March 1, 2022.

³⁶ "The Bio Revolution: Innovations transforming economies, societies, and our lives," McKinsey Global Institute, May 13, 2020.

³⁷ For more, see the GOGO A website.

³⁸ *Sustainability blog*, "A Bio Revolution that could help heal the natural world," blog entry by Michael Chui, McKinsey, May 20, 2020.

³⁹ "The Bio Revolution," May 2020.

⁴⁰ "Orca: The first large-scale plant," Climeworks, accessed September 2022.

- **Sustainable manufacturing and materials.** Besides CO₂ reduction or sequestration, the Bio Revolution has significant implications for sustainability with increasing the use of biological means to manufacture materials, chemicals, and energy. Engineered microbes and yeast are used to produce various materials, and microbes are being used to enhance soil or to make manufacturing processes more effective; Denmark’s Novozymes is a world leader in this area. Germany’s AMSilk and other companies are already making textiles and materials such as silk and nylon with genetically engineered yeast instead of petrochemicals, which provides fully recyclable silk biopolymers.⁴¹ Cement manufacturing is associated with very high carbon emissions. The Dutch company Basilisk is making “self healing” concrete using limestone-producing microorganisms.⁴² The French companies Fermentalg and SUEZ are working together to commercialize genetically engineered algae that can capture CO₂ and transform it into biofuels.⁴³
- **Bioremediation.** Bioremediation involves removing toxins from the environment—soil, water, and the atmosphere—by using biological organisms, including plants, algae, fungi, and microorganisms, such as through wastewater clearance and recycling textiles or plastics. For example, a number of European companies, including Carbios and L’Oreal of France, are part of a consortium that has produced the first food-grade polyethylene terephthalate (PET) plastic bottles entirely from enzyme-recycled plastic.⁴⁴ In environmental policy, nanozymes are being investigated to monitor and counter water pollution. In agriculture and sustainability, engineered bacteria enable agricultural waste to be converted into a variety of products, including spandex and chicken feed.

The Bio Revolution has significant momentum, and the examples mentioned here are just the beginning. It is impossible to fully anticipate what the future will bring, but it is very likely that the confluence of advances in scientific discovery and technology will continue to push the boundaries of what we could until recently only imagine. Many European companies are at the forefront of biology-based innovation. The basics for further progress in Europe are in place, but accelerated momentum will require some bottlenecks and hurdles to be addressed. We need to ensure that demand drives the right incentives and regulation because the Bio Revolution has the potential to address some of the most pressing challenges of our time.

⁴¹ For more, see the AMSilk website.

⁴² For more, see the Basilisk Concrete website.

⁴³ “Fight against climate change: SUEZ Group and FERMENTALG have created ‘CarbonWorks’, a company specializing in the capture and recovery of CO₂ thanks to micro-algae,” Suez Group, July 5, 2021.

⁴⁴ “Global consumer brands unveil world’s first enzymatically recycled bottles,” Carbios, June 24, 2021.

The Bio Revolution has the potential to address some of the most pressing challenges of our time.

About the authors

Matthias Evers is an alumnus of McKinsey's Hamburg office, **Antonia Stein-Asmussen** is a consultant in the Berlin office, and **Nicole Szlezak** and **Alexandra Zemp** are partners in the Zurich office.

Janet Bush, a McKinsey Global Institute executive editor in London, edited this article.

McKinsey & Company

January 2023

Copyright © McKinsey & Company

Cover image: Chad Baker / Getty Images

www.McKinsey.com

 @McKinsey

 @McKinsey

 @McKinsey