

Commentary

Synthetic Biology Industry in China: Current State and Future Prospects

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Received: 31 July 2023; Accepted: 12 September 2023; Available online: 14 September 2023

ABSTRACT: In this article, we provided an overview of the current state of the SynBio industry in China with a focus on its research and technology, its main applications, and major players. We also discussed future prospects including the challenges and advantages of the SynBio industry in China.

Keywords: Synthetic biology industry; China



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1. Introduction

Synthetic Biology (SynBio) is a relatively new field emerged in the early 2000s. There already exist many similar definitions on SynBio but from slightly different perspectives [1–5]. Wikipedia defines SynBio as a new area of biological research that combines science and engineering to design and build (“synthesize”) novel biological functions and systems [1]. Another definition states SynBio is the design and construction of new biological parts, devices, and systems, and the redesign of existing, natural biological systems for useful purposes [2]. According to [6], the element that distinguishes SynBio from traditional molecular and cellular biology is the focus on the design and construction of core components (parts of enzymes, genetic circuits, metabolic pathways, etc.) that can be modeled, understood, and tuned to meet specific performance criteria, and the assembly of these smaller parts and devices into larger integrated systems that solve specific problems. Here we prefer to interpret SynBio from the industrial point of view. Unlike traditional fermentation that relies on artisanal strain engineering, SynBio is a multi-disciplinary domain that integrates biology, engineering and software. Combining automation, high-throughput testing, big data and artificial intelligence, it transforms how biology is engineered and leads to higher efficiency for product research and development. For example, Amyris Inc. built an automated strain engineering platform in 2010, and by 2020, was able to achieve a 5-fold increase in R&D efficiency, an 80% reduction in average time, and 90% lower in average cost for its product development [7].

SynBio is still at an early stage of development globally. The U.S. is widely regarded as the leader in SynBio R&D, with a vibrant ecosystem of academic institutions, research organizations, start-ups, and investors. The U.S. has world renowned SynBio research teams such as the Jay Keasling group at the University of California, Berkeley, and the George Church group at Harvard University. The iGEM originated by MIT has attracted over 75,000 participants since its inaugural competition in 2003. The U.S. has also produced some of the most successful and influential SynBio companies in the world, such as Amyris, Ginkgo Bioworks, Zymergen, Perfect Day, Twist Bioscience, and Impossible Foods. These companies are applying SynBio to various domains including agriculture, biofuels, chemicals, food, and pharmaceuticals. According to a recent paper [8] published by Amyris, they used an automated R&D platform to engineer yeast and produced 454 biochemically diverse molecules within 4 years, an unprecedented achievement in biomanufacturing R&D. The U.S. also has a strong regulatory framework and public support for SynBio development, as well as a pro-bioeconomy policy agenda by the Biden administration that aims to advance American biotechnology and bio-manufacturing. A recently issued Executive Order, “Bold Goals for U.S. Biotechnology and Biomanufacturing” [9], outlined specific goals and steps to strength its competitiveness in a future bioeconomy with an estimated value between \$4 trillion and \$30 trillion USD globally [10]. This is another reflection of the U.S.’ strong ambition in synthetic biology.

In comparison to the U.S., China is still lagging overall in its SynBio R&D, especially in foundational technologies and tools, integrated platforms, and sophisticated strain development. For instance, over 96% patented strains were issued by the American institutions and companies between 1998 and 2018 globally [11]. However, China is not far behind in terms of SynBio capabilities and ambitions. China has a large pool of talent and abundant resources for SynBio research and development, as well as a large domestic market and robust demand for bio-based products and services. China also has a strategic vision and plan for SynBio development, as part of its broader goals to achieve scientific and technological self-reliance and to address environmental and social challenges. In this article, we provided an overview of the current state of the SynBio industry in China with a focus on its research and technology, its main applications, and major players. We also discussed future prospects, including the challenges and the advantages, of the SynBio industry in China.

2. State of SynBio Research and Technology in China

In recent years, China has made bioeconomy a national priority. As a result, SynBio research and its industrialization has become a major focus in its future development plan. Supported by the central and local governments, China has established several centers of excellence for SynBio research and launched several initiatives and platforms such as the China National GeneBank (CNCB), and the China National Center for Bioinformation (CNCB) to foster collaboration and innovation in SynBio. SynBio research has also enjoyed strong policy support from the government. To date, China has made notable progress in developing gene editing technologies, synthetic organisms, and bio-based manufacturing processes.

2.1. Basic Research in SynBio

At the basic research level, China has established a number of SynBio research centers in universities and academic institutions, including the Shenzhen Institute of Advanced Technology (SIAT), the Tianjin Institute of Industrial Biotechnology, Peking University, Zhejiang University, Shanghai Jiaotong University, Westlake University and Jiangnan University (Figure 1). These centers, such as the Institute of Synthetic Biology at the Shenzhen Institute of Advanced Technology and International Joint Research Center of SynBio at Tianjing University, are leading the basic research in bioinformatics, genomics, and metabolic engineering. The past year has seen many synthetic biology research achievements from China published in preeminent international journals. As an example, SIAT published 277 SynBio research papers in 2022, including 28 articles in the Cell/Nature/Science series, and 110 new patent applications. These scientific research achievements demonstrate China's increasing strength in raising the level of basic research in SynBio. It is also worth noting that, recent returnees from abroad have also played an important role to raise the basic research level in China. One such notable example is Dr. Anping Zeng, a renowned scientist in the SynBio field and Member of the German National Academy of Science and Engineering, who joined Westlake University as the founding Director of the Westlake Center of Synthetic Biology and Integrated Bioengineering.

In the realm of foundational technologies, China is rapidly catching up and showing great potential, owing in large part to a growing cohort of exceptional representatives and achievements in DNA assembly [12–14], DNA sequencing [15], DNA synthesis [16,17], gene editing [18–20]. According to BCC Research, the global market for DNA reading, writing, and editing applications will grow from USD 17 billion in 2019 to USD 43.1 billion by 2024 [21]. China is emerging as an indispensable player in this niche market with its remarkable progress.

2.2. Bio-manufacturing Industry

In addition to its basic research, China has the world's leading infrastructure in bio-manufacturing and capabilities to scale up production rapidly and cost-effectively, thereby laying a strong foundation for industrializing SynBio technology. China's annual output of fermentation products exceeds 30 million tons, ranking first globally while accounting for about 70% of the global fermentation capacity. China also leads the world in the production of bulk bio-based products, such as amino acids, organic acids, and vitamins [22] (see Table 1 for its top fermentation companies based on bio-based product revenues). In addition, China has built incubators and dedicated SynBio facilities to enable the commercialization of research and technology. One notable facility is the Shenzhen Industrial Innovation Center for Engineering Biology ("Innovation Center"). The Innovation Center combines the resources from the local government in Shenzhen and the SIAT to establish China's first "upstairs and downstairs" innovation and entrepreneurship complex. Here, "upstairs" researchers engage in original scientific innovation to solve fundamental challenges and support core technological advancements, while "downstairs" provides a platform for industrial incubation, supporting SynBio start-ups with shared laboratory equipment and other resources. This innovative model effectively bridges basic research and industrialization, establishing an enterprise incubation model across the entire chain of scientific research, technology translation, and commercialization.

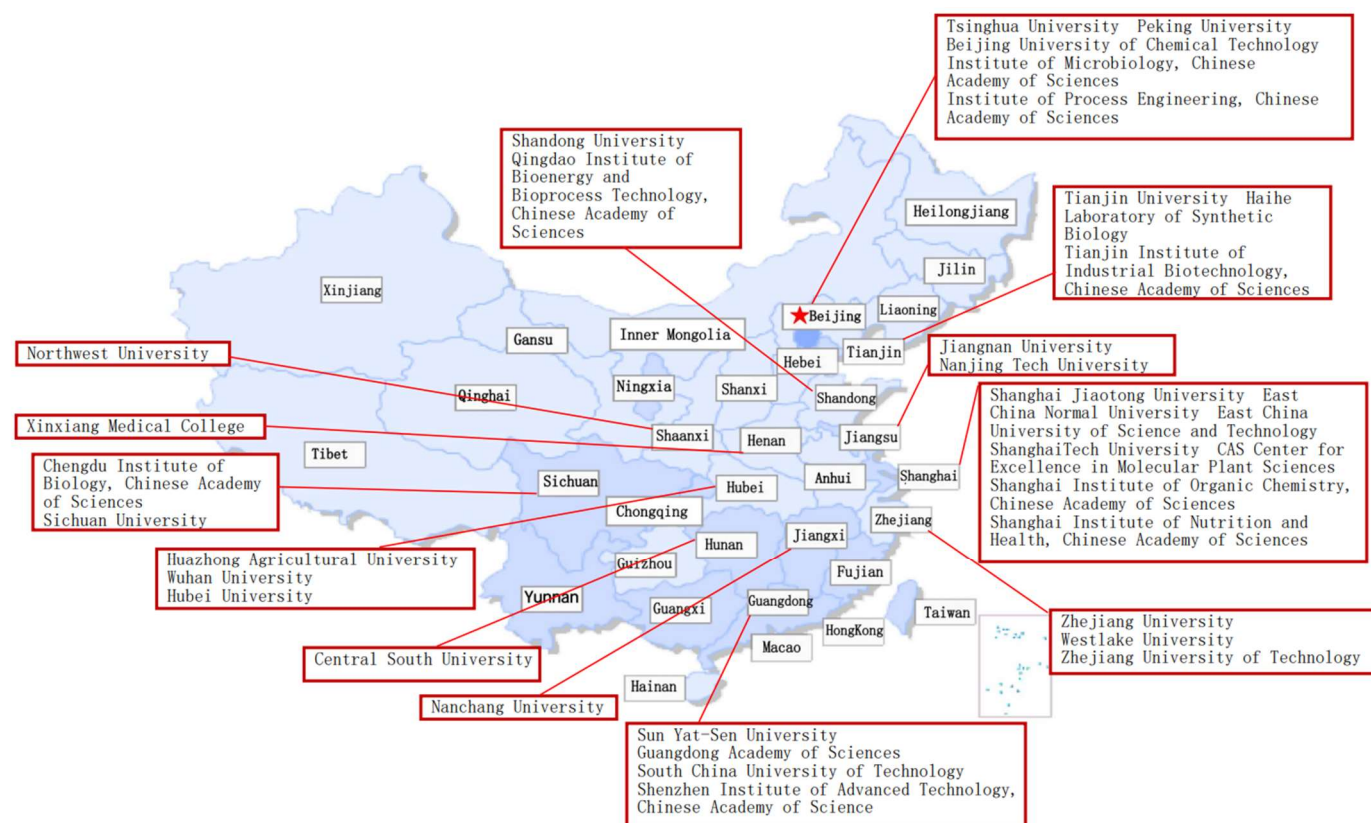


Figure 1. Distribution of representative SynBio researchsh institutions in China, compiled based on publicly available data (Credit: Shenzhen Industrial Innovation Center for Engineering Biology).

2.3. Policy Support for SynBio

SynBio research has been listed in National High-tech R&D Program of China (Program 863) in 2006 and National Basic Research Program of China (Program 973) since 2010. Policy support accelerates since China's 13th Five-Year Plan (See Table. 2). For example, the Ministry of Science and Technology initiated a national key R&D program on “synthetic biology” in 2018; in 2020, the government issued Guiding Opinions on Expanding Investment in Strategic Emerging Industries and Cultivating Strengthened New Growth Points and Growth Poles, which supports various regulations, including the establishment of centers for SynBio technology innovation; in 2022, the National Development and Reform Commission released the 14th Five-Year Plan for Bio-economy Development, targeting cutting-edge areas such as synthetic biology, and implementing major national scientific and technological projects and key R&D programs; in 2023, the Ministry of Commerce, together with the Ministry of Science and Technology and other agencies, revised the Catalogue of Technologies Prohibited and Restricted from Export, by adding “synthetic biology technology” as a technology restricted from export. In addition to the national-level initiatives, various provinces and cities throughout China have also introduced synthetic biology-related policies, establishing the planning and support for the growth of this promising industry in the future.

2.4. Private Investment in SynBio

China's synthetic biology industry has received enormous attention from various investment including the venture capital. Since 2018, financing by the domestic primary market for synthetic biology has been rising year over year, reaching a peak in 2021 in terms of the number of financing events as well as the total investment amount. The market for SynBio remained hot in the first half of 2022 but was slightly cooled in the second half. Despite the overall slowdown in investment by the primary market, private investment in SynBio continued to grow. From 2018 through 2022, the primary market of synthetic biology in China has witnessed 1039 investment and financing events (excluding IPOs, non-IPO listings, secondary listings, mergers and acquisitions, and private placements), involving 456 synthetic biology-related companies. The disclosed total funding exceeded RMB 92 billion [22], with investment hotspots concentrated in the areas of cell and gene therapy, DNA sequencing, automation and high-throughput laboratory equipment, and chemicals. This article compiled statistics on 62 domestic synthetic biology startups, with the summary of results illustrated in Table 3.

Table 1. China's top fermentation enterprises (compiled based on publicly available data).

Corporation Name	Main Products	Market Cap (Billion RMB)	Bioproduct Revenue (Billion RMB)
Meihua Group	Food additives, condiments, amino acids, colloids, capsule, fertilizers	26.2	27.9
Fufeng Group	Food additives, amino acids, hydrocolloids, animal nutrition, condiments, pharmaceutical care, beauty care, fertilizers	10.1 billion HKD	27.4
COFCO BIO	Fuel ethanol, citric acid, L-lactic acid, ethylene oxide, amino acids, corn gluten meal and slag feed	13.8	19.9
Star Lake	Disodium guanosine 5'-monophosphate, inosine, L-Threonine	9.1	17.5
NHU Group	Animal and human nutrition, aroma chemicals, special chemicals and APIs	49.5	15.9
Angel Yeast	Baker's yeast, bread improver, raising agent, pre-mix, other ingredients	30.5	12.8
United Laboratories	Medical intermediates, active pharmaceutical ingredients (APIs) and pharmaceutical preparations	11.2 billion HKD	11.3 billion HKD
North China Pharmaceutical	Chemicals and bio-based pharmaceuticals, vitamins and nutritional health products, modern Chinese medicine, agricultural and veterinary drugs	9.6	10.5
Sinopharm Weiqida Pharmaceutical	Antibiotic intermediates, pharmaceutical raw materials	14.7	5.0
BBCA Pharmaceutical	Biopharmaceuticals, chemical pharmaceuticals, Chinese patent medicines, Chinese herbal decoction pieces, and APIs	3.2	4.0
Chuaning Biotech	Antibiotics and pharmaceutical intermediates	19.6	3.8
Cathay Biotech	Long-chain dibasic acids, bio-based pentamethylene diamine, and bio-based polyamides	36.1	2.4
Huaheng Biotech	Alanine series products (L-alanine, DL-alanine, β -alanine), calcium D-pantothenate and α -arbutin	14.2	1.4

Table 2. Major policy support since China's 13th Five Year Plan (2018–2023).

Time	Government Agency	Policy Name	Detail	Investment Scale
2018	Ministry of Science and Technology	The 13th Five-Year Plan and the Special Plan for Biotechnology Innovation	Put forward specific goals in improving level of the originality of biotechnology, building a biotech innovation platform, strengthening the production of biotechnology, and set the frontier key technologies to be broken through, including new generation of biological detection technology, synthetic biology, nanobiotechnology.	In 2019, the Shenzhen Municipal People's Government signed a framework agreement on the Joint Ministry-City Cooperation for the Implementation of the Key Special Program "Synthetic Biology" under the National Key Research and Development Plan. The central government and Shenzhen jointly funded the implementation of the "Synthetic Biology Key Special Program", with a total project budget of approximately 2.3 billion yuan.
2020	National Development and Reform Commission, Ministry of Science and Technology	Guiding Opinions on Expanding Investment in Emerging Industries, Cultivating and Strengthening New Growth Areas	Support the construction of the synthetic biology technical innovation center, promote biotechnology development.	In 2019, the Ministry of Science and Technology officially approved the National Synthetic Biotechnology Innovation Center. It is jointly built by the Chinese Academy of Sciences and the Tianjin Municipal People's Government, and led by the Tianjin Institute of Industrial Biotechnology of the Chinese Academy of Sciences. The total investment is about 2 billion yuan.
2021	National Development and Reform Commission, Ministry of Industry and Information Technology	Notice on the Implementation Plan for Promoting the High-quality Development of the API Industry	Accelerate development and application of advanced technologies such as synthetic biology, continuous microfluidics and continuous crystallization control, and focus on the development of advanced technologies such as synthetic biology and enzyme engineering.	No information available
2022	National Development and Reform Commission	The 14th Five-Year Plan for Bio-economic Development	Emphasize the bioeconomy including synthetic biology as the new driving force for China's future economic transformation.	No information available
2023	Ministry of Commerce	Catalogue of Technologies Prohibited and Restricted from Export	Add the SynBio technology as a technology restricted from export.	No information available

Table 3. Statistics of classified domestic startups in SynBio, compiled based on publicly available data (Credit: Shenzhen Industrial Innovation Center for Engineering Biology).

Company Name	Year Founded	Latest Financing	Main Business
<i>Tool-focused (10)</i>			
EdiGene	2015	Series B/RMB 400 million	Genome editing
Tsingke Biotech	2017	Series A/nearly RMB 200 million	DNA synthesis (including instruments, reagents, and raw material carriers)
Axbio	2017	Series B/nearly USD 100 million	Genome sequencing and diagnostic equipment
Dynegene Technologies	2018	Series A/nearly RMB 100 million	High-throughput DNA synthesis
Boke Bioscience	2019	Pre-A/RMB 10+ million	High-throughput DNA synthesis
C-ATOM	2021	Angel/RMB 10+ million	DNA data storage
Atantares	2021	Angel/RMB 10+ million	Molecular chip-based DNA synthesis
Zelixir Biotech	2021	Pre-A	Protein structure prediction and design and related applications
Molecule Mind	2022	Strategic investment/RMB 100+ million	AI protein design
Zhonghe Gene	2022	Angel/RMB 10+ million	High-throughput DNA synthesis and equipment
<i>Platform-focused (9)</i>			
Huili Bio	2003	Series A/RMB 300 million	Next-generation synthetic biology enzyme computational design
Enzymaster Bio-Engineering	2013	Series C/nearly RMB 300 million	Enzyme directed evolution
LifeFoundry	2016	Angel/USD 2.2 million	DNA design, strain construction, and strain screening
Synbiolab	2017	Pre-A/RMB 10+ million	Full industry chain, with a focus on high-value-added compounds
Synceres	2019	Series A/nearly RMB 100 million	Enzyme improvement, optimization through alternative pathways
Bota Bio	2019	Series B/USD 100 million	Synthetic biology platform
Ailurus Biotechnology	2020	Angel/RMB 10+ million	Biology computing
Tidetrone Bioworks	2021	A+/USD 100+ million	Full industry chain
Yuanteng Bioengineering	2022	Angel	Biological synthetic peptide
<i>Application-focused - Agriculture and Food (8)</i>			
Changing Bio	2017	Series A/RMB 140 million	Microbial alternative proteins
BellaGen	2018	Series A	Plant gene editing
Juwei Yuanchuang Biotechnology	2018	Series A/RMB 100 million	Biological transformation technology
Joes Future Food	2019	Series A	Cultured meat
Zhenrou Food Technology	2019	Seed	Pea protein meat
Yixi Biotech	2019	Pre-A	Synthesis and production of carbohydrates
Zeno Biotech	2021	Angel/RMB 10 million	Gene engineering of Escherichia coli and yeast as the chassis bacteria
Green Bio	2022	Seed/RMB 10+ million	Nitrogen-fixation
<i>Application-focused - Chemical Industry, Raw Materials, Materials (16)</i>			
Leadsynbio	2015	Series C+/RMB 100+ million	Medicine, nutrition and health care, animal health care, and plant protection
Ingia-Bio	2015	A/RMB 10+ million	Steviol glycosides, mogroside, allulose, ferulic acid, vanillin
Hzymes Biotech	2015	Series C/RMB 800 million	Specialty enzymes
Viablif	2015	A+	Natural products
Bluepha	2016	Series B/RMB 400 million	Molecular and material innovation
Readline	2017	Series B/RMB 300 million	Immobilized enzyme catalysis
Seven Company	2020	Angel	Green functional cosmetics and health products raw materials
SynMetabio	2021	Angel	New materials
Cataya Bio	2023	Series B/RMB 250 million	High value bio-based products
GsynBiot	2021	Pre-A/RMB 10+ million	Ginsenoside monomers and other natural compounds

PhaBuilder	2021	Series A+/RMB 359 million	Polymer material PHAs
Sipeng Technology	2022	Angel/RMB 10+ million	Advanced manufacturing of bio-based products
Evolyze	2022	Angel/RMB 50 million	High stress-tolerant biocatalysts, bio-template-based nanometer and single-atom metal catalysts, and high value-added specialty chemicals
Enlogics	2022	Angel/RMB 50 million	Green biological products
Zhihe Biotechnology	2022	Angel/RMB 10+ million	Oleochemicals
Synthera	2022	Angel/RMB 10+ million	Industrial enzymes and enzyme catalysis
<i>Application-focused - pharmaceuticals (11)</i>			
Yacht Biotechnology	2004	Series A/RMB 100 million	High-end microbial pharmaceutical products
Syngentech	2014	A/RMB 10+ million	Synthetic biology technology services and research products
Bioforany	2014	Angel/nearly RMB 50 million	Mining and transformation of industrial enzyme genes
Geneo Medicine	2018	Series A	Product pipeline for a range of clinical indications, including tissue injury and degenerative diseases
AsiFlyer Biotechnology	2018	Angel/RMB 50 million	Macromolecular drug delivery
Proxybio	2020	Seed/RMB 10+ million	mRNA drug development
Roc Rock Biotechnology	2021	Angel/RMB 10+ million	Solid tumor cell drugs
Biocre Tech	2021	Pre-A/RMB 10+ million	Protein molecular design and synthesis
Dekonix Bioworks	2021	Seed/USD 14 million	Synthetic vaccines and live bacterial drugs for infectious diseases and tumors
U-SynBio	2022	Angel/RMB 10+ million	Live biotherapeutic products (LBP)
MicroCyto	2022	Angel/nearly RMB 100 million	Active pharmaceutical ingredients, high-value-added natural products, and bulk platform compounds
<i>Application-focused - Health and medical aesthetics (8)</i>			
SIYO Bio-Tech	2015	Series B/nearly RMB 200 million	Bioactive ingredients
Shinhigh Innovation	2017	Series A/nearly RMB 200 million	An industrialization platform for technology in the big health industry
Mojia Biotech	2018	Series B/USD 80 million	Green biomanufacturing, such as vitamins
Hernrrie Biotechnology	2019	Series A	Raw materials to medical products, functional skin care products, and medical aesthetics
Stee Hill	2019	Strategic investment/RMB 10+ million	Skincare
DMT Biotechnology	2019	Angel/RMB 10+ million	Microalgae-based products
Veminsyn	2021	Pre-A/nearly RMB 50 million	Recombinant collagen
PAML Biotechnologies	2021	Pre-A/RMB 100 million	Bio-based materials

3. Main Applications of SynBio

Research and Markets predicts that the SynBio industry in China is expected to reach a market size of USD 2.9 billion by 2026, with a compounded annual growth rate of 32.4% from 2021 to 2026 [23]. The combination of macro policies, scientific research, and technological advancements has enabled the Chinese SynBio industry to thrive in a variety of fields including agriculture, chemical and energy, food and nutrition, and healthcare.

3.1. Agriculture

SynBio can help increase agricultural productivity, improve crop quality, and reduce production costs, achieving sustainable development. The applications of synthetic biology in agriculture mainly involve crop yield improvement, pest control, animal feed, crop quality improvement, etc. For example, microbial or metabolic engineering techniques can be used to reduce the use of agricultural fertilizers and reshape metabolic pathways to improve crop quality. Guta Biotechnology has performed multi-gene editing on the key steps of the DHA metabolic pathway in *Schizochytrium* sp., leading to high-level accumulation of lipids. Source Species Biotech has used gene editing technology to breed peanuts with high oleic acid content.

3.2. Chemicals and Energy

SynBio holds enormous potential in helping the chemical and energy industry to transition away from petroleum-based manufacturing and building a new sustainable path for green industrialization [24]. The main applications of SynBio in the chemical industry include materials and chemicals, industrial enzymes, and biofuels. For example, modified yeast and other microorganisms can be used to produce chemicals, materials, and oils, and high-activity enzymes can be created through directed evolution combined with high-throughput screening. BBKA Group, a leading industrial biotech company in China that manufactures bio-based lactic acid, citric acid and amino acids, recently completed its PLA (polylactic acid) plant with a 100k MT capacity. Bluepha, a rising SynBio startup, has raised approximately \$300M to develop strains and processes to produce fully bio-based, biodegradable materials known as PHAs (polyhydroxy alkananoates).

3.3. Food and Nutrition

SynBio technology can help explore the key genetic elements for the synthesis of nutrients and functional components in animals and plants, disrupting the existing methods of food production and processing. The applications of SynBio in food and nutrition mainly include meat and dairy products, beverages, food ingredients and additives, among others [25]. For example, based on traditional food manufacturing technology, synthetic biology can be used to modify synthetic pathways, optimize and coordinate protein expression, construct new cell factories, and produce various types of food. Shanghai-based CellX has developed serum-free culture media and used protein recombinant technology to develop purine-free beer.

3.4. Healthcare

Breakthroughs in enabling technologies such as DNA sequencing and DNA synthesis, and gene editing have opened up an accelerated development window for SynBio, bringing about disruptive innovations in traditional pharmaceutical manufacturing that could lead the future of the industry. The primary applications of SynBio in healthcare include cell immunotherapy, RNA drugs, microbiota therapy, gene editing-related applications, in vitro diagnostics, medical consumables, and pharmaceutical ingredient production of both small molecules and proteins. For example, mRNA technology can be used to rapidly create vaccines, while gene editing can be employed to treat genetic diseases, design cell behavior and phenotype to precisely modulate immune cells for tumor treatment, develop rapid and sensitive diagnostic agents, transform microorganisms for the production of medical consumables and pharmaceutical ingredients, and generate artificial phages for disease treatment. Legend Biotech has developed China's first cell therapy drug and received FDA approval for marketing it in the U.S. Xbiome, a Shenzhen-based SynBio startup, has developed XBI-302, a fecal microbiota transplant drug candidate that has recently obtained FDA IND approval for clinical trials.

4. SynBio Companies and Major Players in China

Chinese companies in the SynBio industry can be broadly categorized into tool, platform, or product-focused. According to incomplete statistics from Bestla [22], there were 925 SynBio-related companies in China. These include 441 tool companies (47.6%), 54 platform companies (5.8%), and 430 product companies (46.4%). The tool companies engage in upstream work, specializing in providing DNA/RNA synthesis, sequencing, and genomics, as well as data-related SynBio foundational technologies, products, and services. The platform companies focus on strain construction, accumulating data through extensive experimentation, and offering technical platforms for the design and development of biological systems and organisms. The product companies seek to commercialize products, offering development and practical applications which are used in a variety of domains encompassing human life, including agriculture, food, energy, chemical industry, medical and cosmetic fields.

From a geographical perspective, the most representative synthetic biology companies in China are mainly located in five regions—Beijing, Shanghai, Jiangsu, Zhejiang, and Guangdong. The industrial development in the Yangtze River Delta region and the Guangdong-Hong Kong-Macao Greater Bay Area exhibits robust momentum and tremendous potential for growth. This article conducted a statistical analysis of 105 representative SynBio companies in China, classified them into eight major sectors based on their primary business focus and counted the number of representative companies in each sector (Figure 2). These eight sectors include agriculture, biological construction & automation platform, chemical, consumer goods, DNA/RNA synthesis, energy, food, and pharmaceutical. The number of companies in pharmaceutical, chemical, and biological construction & automation platform ranked in the top three. From a lens of regional representative enterprises, Beijing, Shanghai, and Jiangsu Province have a major share of companies in the pharmaceutical sector, while Zhejiang has a predominant presence in the pharmaceutical and chemical sectors. Companies from Guangdong focus primarily on consumer goods and biological construction & automation platforms. This presents the aggregative effect of regional development and the differentiation of competition across regions.

A number of SynBio companies have emerged as leaders in various markets in China. In biomaterials, Cathay Industrial Biotech has been a primary supplier of fermentation-derived long-chain dicarboxylic acids and is developing a biomanufacturing process to produce pentamethylene diamine, breaking into the bio-based polyamides market. Anhui Huaheng Biotechnology has unleashed its production capacity for L-alanine and L-valine, establishing itself as an important player in amino acids. In personal care, Bloomage Biotechnology, the leading supplier of hyaluronic acid, has been building its SynBio research capabilities in an effort to broaden its cosmetic ingredient as well as consumer product pipelines. In food and agriculture, Biosysen has utilized software engineering concepts to guide species design, launching a line of craft beers designed based on bacterial strains, which have been highly acclaimed by the market.

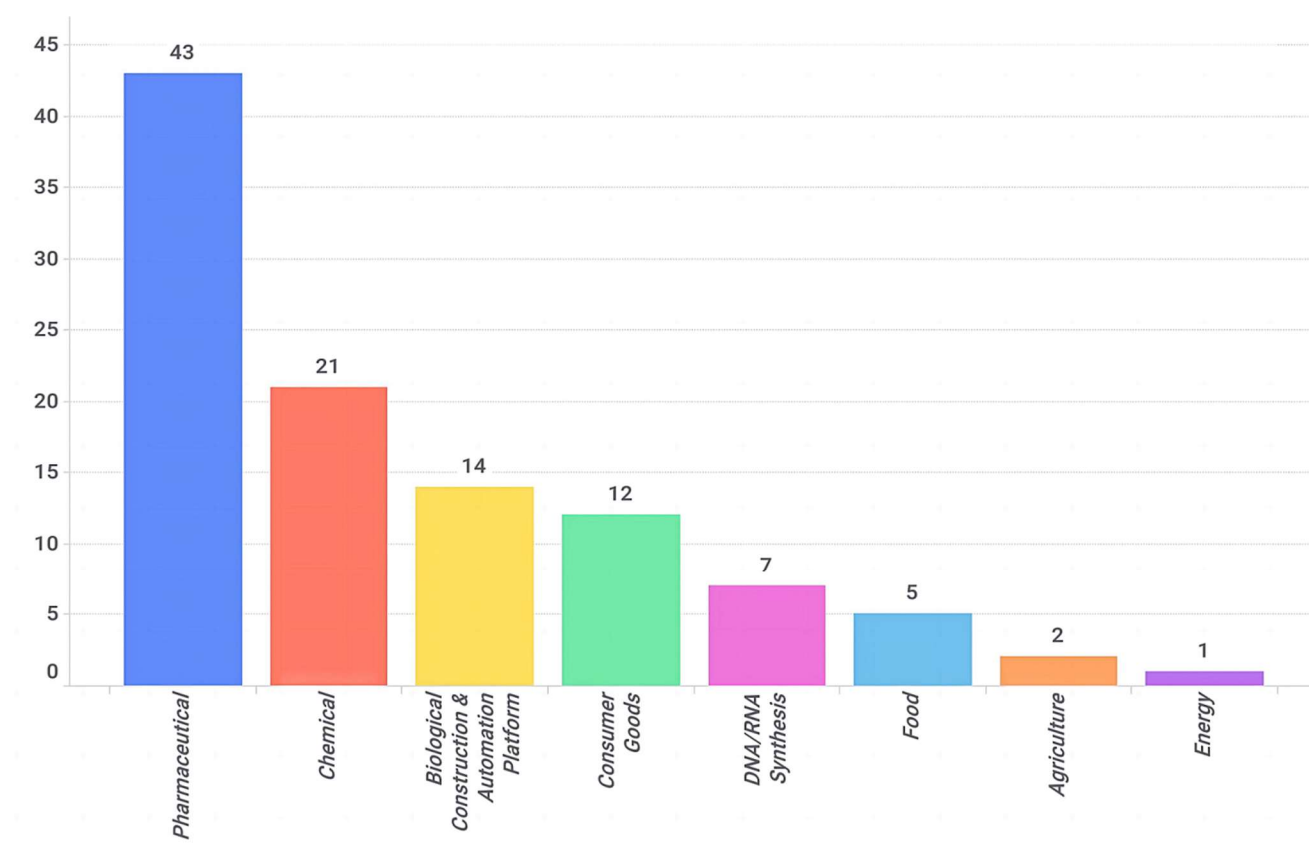


Figure 2. Distribution of representative SynBio companies in China by sector, compiled based on publicly available data (Credit: Shenzhen Industrial Innovation Center for Engineering Biology).

5. Prospects of SynBio industry in China

According to a report by McKinsey, over 60% of products in the global economy can be produced using biotechnology, and nearly 400 application scenarios are expected to generate a direct economic impact of up to USD 4 trillion over the next 10–20 years [26]. Synthetic biology is regarded as a critical industry for the future and has become a subject of competition among nations. As far as China is concerned, the prospects for the synthetic biology industry are promising if it can overcome some of its challenges while strengthen its many advantages.

5.1. Challenges Faced by the Chinese SynBio Industry

The SynBio industry has experienced a period of rapid expansion since 2010, with both traditional chemical companies and emerging enterprises actively developing layouts in this exciting field [27]. The development of synthetic biology technology relies on basic research, while the commercialization of scientific research findings requires a well-established industrial model and supportive government policies. In recent years, China has accelerated its efforts in basic research, industrial development, and policy support for SynBio, propelling the entire industry into a fast lane of growth with enormous developmental opportunities, but not without challenges.

From a technological perspective, China currently faces challenges in two areas: technological innovation and technological barriers. In terms of technological innovation, China has yet to overcome the issue of affordable long-chain DNA synthesis, with the cost being still too high and the turnaround time being too long for routine use in R&D. Furthermore, for the modification of high-yield strains that are difficult to genetically manipulate, the current metabolic pathway predictions and model designs require improvement to establish more generally applicable and efficient technologies. The constraints of technological barriers mainly lie in intellectual property rights and advanced R&D equipment. China is significantly lagging in the intellectual property rights for some core technologies, such as the creation of biocatalysts, core strains, and key enzymes, which are still controlled by other countries including the U.S. As for R&D equipment, China lacks a system centered around microbial reactors, process sensing and detection, and biotechnology software engineering based on technologies such as big data and artificial intelligence. Critical components of fermentation equipment, such as stirring probes, sensors, and temperature regulators, have long been monopolized by imported equipment companies. To achieve its ambition of becoming a global leader in the SynBio industry, China must create its own technological advantages and break foreign technological monopolies.

In industrializing SynBio technology and creating an innovative industrial ecosystem, there also exist significant challenges, mainly in the following three aspects that require government policy to help address:

- (1) Fostering a favorable environment for intellectual property protection. The risk of loss or theft of research results, such as synthetic biology strains, is high, especially in the booming industry, where a rapid and coordinated system for protecting intellectual property is crucial to promote a benign competition structure within the industry.
- (2) Building a relatively flexible regulatory system. In fields such as food and beverage, healthcare, agriculture, forestry and animal husbandry, chemical industry, and energy, product safety and quality are paramount. China's biosafety regulatory system still needs improvement. For cutting-edge technologies such as gene editing, microbial therapy, and genetically modified organisms, application standards, and norms should be clearly and promptly defined. For policy tools, flexibility, coordination, and support functions should be strengthened. Pilot windows should be actively promoted, allowing innovation to be first tested on a small scale. Equally important is to accelerate the examination, approval, and market access of innovative biotech products by simplifying the regulatory process.
- (3) Establishing sustained support of preferential policies. As a cutting-edge innovative technology, synthetic biology has high R&D costs and trial-and-error costs. The period from basic research to industrialization is typically long. It is therefore essential for the government to create necessary policies to support project incubation and drive the overall innovation of the industry forward.

5.2. Advantages of the Chinese SynBio Industry

China's SynBio industry and market differentiates itself from rest of the world in a few main aspects. Firstly, China has a significant cost advantage in upstream R&D and even more so in downstream process and scale up manufacturing owing to cheaper labor cost and more complete infrastructure. Secondly, China's vast population and extensive resources offer unique advantages to its SynBio industry. The country's large market size creates opportunities for testing, manufacturing, and commercializing synthetic biology products. China's abundant biological resources, including diverse ecosystems and genetic diversity, contribute to a rich pool of genetic material for bioengineering. Thirdly, China has a large and highly skilled workforce, including scientists and engineers with expertise in SynBio. China also actively engages in international collaborations and investments with global companies, research institutions, and startups to share knowledge, technologies, and market access to foster the growth of its SynBio industry. Fourthly, SynBio is in line with China's ambitions to reach the peak of carbon emission by 2030 and achieve carbon neutrality by 2060, as stated by President Xi at the General Debate of the 75th Session of The United Nations General Assembly in 2020. This creates a golden opportunity for the whole SynBio sector since it is deemed as the silver bullet to tackle the issue of carbon emission and transition away from fossil fuel-based manufacturing.

As China continues to advance its basic research and develop foundational technologies in SynBio, strengthen its lead in industrializing SynBio, in particular, by upgrading its industrial research and development capabilities while leveraging its dominant advantages in biomanufacturing infrastructure and a low-cost skilled workforce, it will be able to maintain a long-term competitiveness in SynBio industry. With the support of sound policy environments, the SynBio industry China is expected to enter a critical phase of breakthroughs and sustained growth in the coming years.

Acknowledgements

We thank Dr. Yuliang Huang for his support and comments, and Dr. Liuyang Diao for his suggestions in writing this manuscript.

Author Contributions

Conceptualization, L.Z. and W.L.; Writing—Original Draft Preparation, W.L., Y.Z., J.P. and L.Z.; Writing—Review & Editing, W.L., Y.Z., J.P. and L.Z.

Ethics Statement

Not applicable.

Informed Consent Statement

Not applicable.

Funding

This research received no external funding.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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