



## A brief overview of global biotechnology

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## A brief overview of global biotechnology

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### ABSTRACT

Biotechnology is an innovative, interdisciplinary field that impacts many different sectors, including agriculture, veterinary, medicine, pharmaceutical and fine chemicals production. It is emerging as one of the leading technologies for the transition towards carbon-free society and for solving critical societal challenges comprising health protection, food and energy supply, and environmental protection. Professional networks such as EBTNA (European Biotechnology Thematic Network Association) are important to disseminate knowledge and raise awareness of biotechnology as one of the key enabling technologies for sustainable production.

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## Categories of biotechnology industries in the world

The dramatic development of molecular biology, which led to the creation of new scientific fields such as genomics, proteomics, and metabolomics, resulted in an explosion of biotechnological applications at the turn of the twenty first century. Among the most prominent of these applications were the production of a large number of vaccines that prevent many infectious diseases, and development of more efficient, nutritious and durable hybrids of plants and animals. It is also worth noting that various industrial products such as ethanol, organic acids, antibiotics and biodegradable plastics have been developed as applications related to improved food preservation [1]. There are genome editing technologies that are well-established research tools, with CRISPR/Cas9 being one of

the most prominent examples. These technologies hold great promise as a basis for the future growth of gene-based biomedicine [2], as well as the use of biotechnology as the key enabling technology for industrial production of pharmaceuticals and fine chemicals [3]. The perspective of advancing biotechnology in the society is one of the missions of professional organisations such as the European Biotechnology Thematic Network Association (EBTNA). As part of its role in promoting awareness of biotechnology, the EBTNA has published several reviews that address the growth of the biotechnology industry [2, 4–9].

It is possible to classify the biotech industry into sectors that include biopharma, industrial biotechnology, agricultural biotechnology, food biotechnology, environmental biotechnology and bioinformatics. The proportionate contributions to the global biotech industry of these sectors are shown in Figure 1 [10].

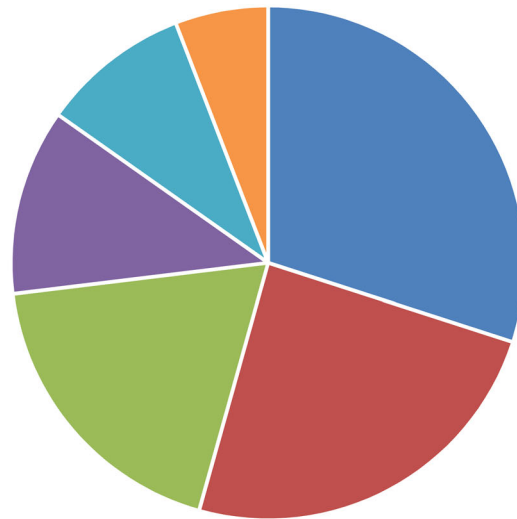
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†Prof Munis Dundar is the President, and all authors are members of the Executive Committee for the European Biotechnology Thematic Network Association (<http://www.ebtna.eu/>)

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■ Bio Pharma ■ Industrial biotech ■ Agricultural biotech ■ Food biotech ■ Environment ■ Bio informatics

**Figure 1.** Categories within the global biotech industries [10].



**Figure 2.** Market size, number of businesses and employment in 2019 biotechnology world-wide.

The worldwide growth rate of biotechnology between 2015 and 2020 is 1.3%. It is expected that the biotechnology sector will achieve a steady increase in the next five years and that more investments will be made in research and development (R&D) worldwide [11]. The statistical data related to the world biotechnology market size, number of businesses and employment for 2019 are shown in Figure 2 [11].

### Biotechnology market in Europe

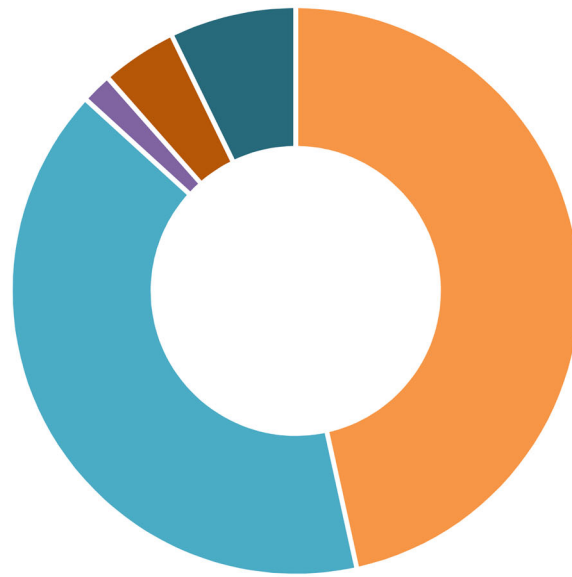
Biotechnology contributes to the modernization of the European industry. Biotechnology is used in various industrial sectors such as human health and pharmacy,

animal health, agriculture, textiles, chemicals, plastic, paper, fuel, food and feed. Benefits from biotechnology both help the EU economy to grow and provide new jobs to individuals, and support sustainable development, public health and environmental protection. Figure 3 shows the country-based distribution of biotechnology research [12].

In 2005, biotechnology was the leading world industry in comparison with the agriculture and pharmaceutical industries. From 2010 to 2020, more emphasis has been placed on biotechnology in the pharmaceutical field in the world. Even if agricultural biotechnology has been increasing steadily between 2005 and 2020, a clear trend towards larger growth in the pharmaceutical sector has been observed world-wide (Figure 4) [10].

Demographic changes, increase in life expectancy, changes in disease patterns, social globalization, a significant increase in the access to health services and the emergence of the social state have played a crucial role in the growth of the world pharmaceutical industry. The total trade volume of the pharmaceutical industry in the world has been above 1.35 trillion USD. The enormous demands and consumption in developed countries is met by production in these developed countries. According to Trademap 2018 data, world pharmaceutical exports amount to 656 billion USD. The share of the top 10 leading countries in pharmaceutical exports in total exports is 78% (Figure 5) [13].

The global biotechnology sector, which has been on the rise since the 1980s, is generally concentrated in high-income countries. Most of the investments made in the field of biotechnology belong to the USA



USA Europe Asia Pacific Middle East countries Other countries

Figure 3. Biotechnology Research in the World [12].

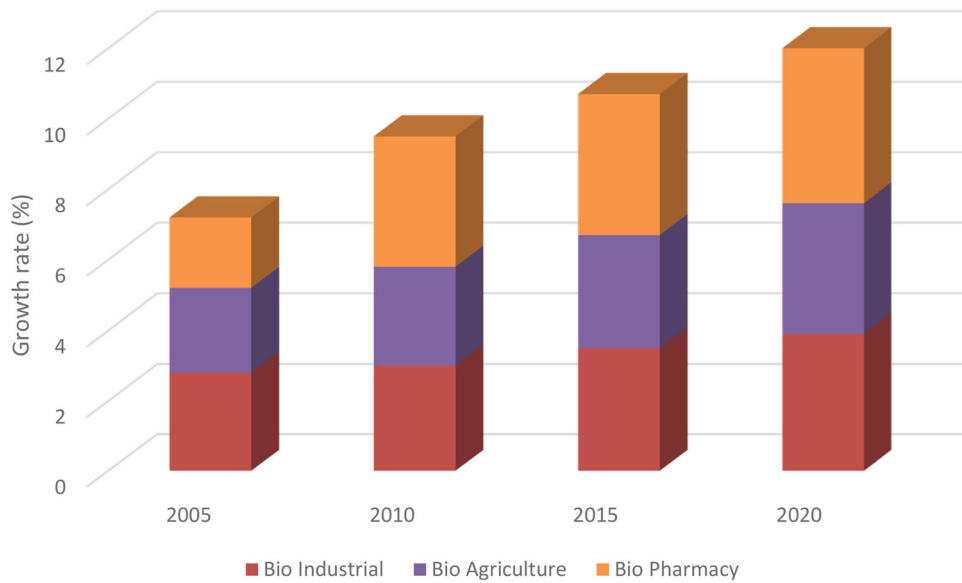


Figure 4. Comparison of biotechnology fields in 2005, 2010, 2015, and 2020 [10].

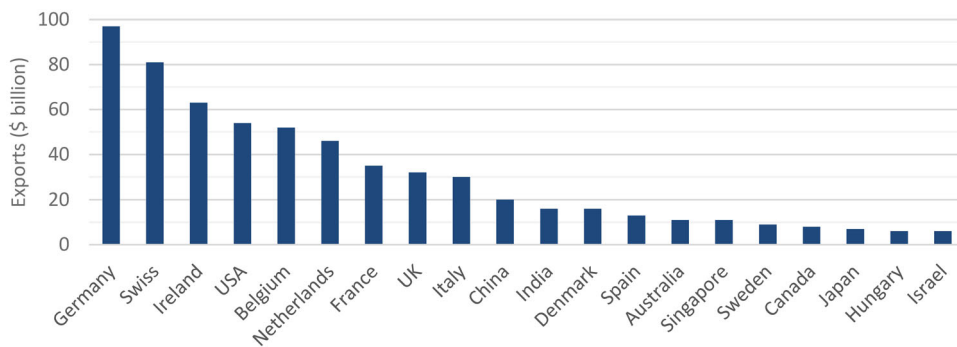


Figure 5. Top 20 countries in the world pharmaceutical exports (billion \$) [13].

**Table 1.** Biotechnology activities in the world.

Country	Biotechnology Focus
USA	When it comes to biotechnology, the United States is at the forefront. Since 2014, the US government's investment and support in the biotechnology field have reached record levels [17]. However, we can say that 97% of the mentioned bioindustrial income and 96% of employment is realized in the USA, Canada and European countries. According to statistics, there are 318 companies in the USA (annual turnover of 33 billion USD), on the basis of large companies with official records. It has been reported that a budget of 20.5 billion USD has been dedicated to R&D studies in the field of Biotechnology in the USA and 7.6 billion USD in Europe in previous years [18].
United Kingdom	UK has been making serious studies and investments in drug discovery with biotechnological approaches on genetic coding, DNA nucleotides and the like [17]. It is estimated that approximately 183 thousand people are employed in the life sciences sector in England alone. Of this number, 23 thousand are employed in the field of medical biotechnology and 3 thousand in the field of industrial biotechnology. The business volume in medical and industrial biotechnology is calculated as 5.7 billion pounds for 2014 [19].
India	Having the second largest population in the world, India has seen that the biotechnology field is one of the important branches of the industry, and the government has included biotechnology in its programs [20]. India is one of the leading countries that attach importance to biotechnological studies in agricultural productivity and environmental protection. There has been a noticeable increase in the investment in biotechnology from the government of India each year. Four hundred four million Rs from 1986 to 1987; an increase of 1.138 million Rs from 1997 to 1998 and 1.863 million Rs from 2001 to 2002 was observed. More than 62 organizations are currently busy preparing projects related to biotechnology. India tends to be more remarkable in bioinformatics [21].
Finland	Finland, underperforming so much in the field of biotechnology before 2009, focused more on biotechnology afterwards. In Biotec Therapies, a biotechnology company now based in the USA, drug development is carried out specifically to treat Parkinson's disease [17].
Israel	Israel is a fast-growing country in biopharmaceutical and biotechnological industries. Israel pioneered in bio-incubators [17] and has had unicorns such as Teva's Copaxone creating multi-billion dollar revenues. Furthermore, the academic setting has pioneered numerous start-ups with many these days in the hi-tech of biotech (1,400+) including, medical devices (450+), pharmaceutical (300), digital health (300+), utilizing AI, clouds, mobile, BIG data. Investments are in the billions and NASDAQ exhibits also billions in companies related to Life sciences.
Italy	The biotech industry in Italy is decreasing every year. The reason for this is the difficult economic conditions of Italy. Despite these economic conditions, they are engaged in working activities in biofuel production and biopolymer manufacturing [17].
Sweden	Sweden cannot focus on the field of biotechnology due to the difficulty of being prominent in international collaborations. Despite this, Lund University, Uppsala University, Karolinska Institute and Stockholm University continue studies on the development of anti-cancer drugs. In these studies, they especially focus on biomarkers [17].
Cuba	Today, biotechnology products constitute the second most important export item of Cuba [22]. Although the field of activity of the biotechnology sector in Cuba includes areas such as agriculture, animal husbandry and environment, health services have always been included in the center so that the biotechnology sector is defined as a subcomponent of the Cuban health system [23].
Germany	Since 2013, Germany has been developing in the field of biotechnology, based on international cooperation. In a study conducted with hepatocytes in 2015, they obtained liver cells in a laboratory environment. The most important company in Germany in biotechnology and genetics is QIAGEN [17].
Japan	Since 2010, devices have been produced to create neural networks from pluripotent stem cells in Japan, which has shown an increasing trend in biotechnology. They have developed promising treatments for the connections between neurons and various organs in patients with peripheral nervous system damage [17].
South Korea	South Korea has been foreseeing and making investments in biotechnology since the 1980s. South Korea has focused on GMO foods and pharmaceutical treatments. Food and animal husbandry has been prioritized in biotechnology. With the foresight of South Korea's biotechnology in the 1980s, the development up to this time has risen to produce 68% of the various products used by South Korea in the field of biotechnology [24].
New Zealand	New Zealand is one of the countries with a lot of biotechnology, especially biodiesel production. A biodiesel plant was established there in 2015. As a policy, it is aimed to increase the amount of biodiesel produced each year above the previous year [17].
Taiwan	National Taiwan University, which has progressed in the field of biotechnology, has achieved to be among the top 100 in the world in this field. The fact that the state started making investments in the field of biotechnology in 2016 proves the need for progress in this field [17].
Australia	Melbourne is seen as the center of science and biotechnology studies in Australia. The Australian government supports academic institutions and R&D work at the public level. Biotechnology studies for cancer treatment continue at cancer institutes, which costs 750 million USD [17].
Singapore	In 2015, a synthetic biology center was opened at the National University of Singapore, and 25 million USD was spent for this center. The Singapore government has allocated 13.2 billion dollars for science between 2016 and 2020. Singapore advances in science and biotechnology every year [17].
France	There are 627 companies in the field of biotechnology in France. The public's share in this area is 9%. The government of France has invested 6.3 billion euros in the field of biotechnology in the last 5 years. In addition, private companies make huge investments in the field of biotechnology. In general terms, it is seen that pharmacological investments in France are more than other biotechnology sectors [25].
China	China has made progress in biotechnology in terms of competence and knowledge, although being well below the technology frontier in the early twenty first century [26]. Biotechnology is becoming increasingly important in China. China has specialized in industrial biotechnology in the last 10 years, inter alia in the field of biopolymer manufacturing. It is seen that it lags behind in the field of medical biotechnology compared to other countries [27].
Spain	In 2018, the Spanish biotechnology sector invested about 770 million € in R&D, 71% from private biotech companies, which represented an increase of 13% over the previous year. About 750 specific biotechnology firms were registered in Spain, although almost 3000 in total carried out biotechnology activities. Close to 50% of those companies work on human health and related fields and 38% on agricultural and food biotechnologies. A large proportion of the Spanish biotech companies are micro-SMEs, with less than ten employees. The joint income of the biotech sector was over 8.2 billion € in 2018, 0.8% of the GDP, providing jobs for 105,000 people [28]
Turkey	Turkey's biotechnology activities from the 1980s have begun to gain importance. Although these activities in the field of biotechnology have increased in each year, it is seen that it has still not reached the desired level [9].

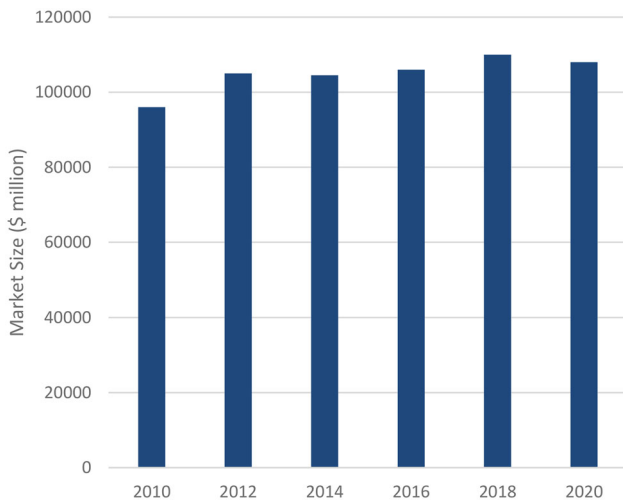


Figure 6. Market size of biotechnology in the USA during the period from 2010 to 2020 [30].

and EU member states, and it is estimated that less than 5% of the total investments are made by developing countries [14].

The weight of the private sector in the financing of scientific studies worldwide is gradually increasing. For example, private companies finance 64% of scientific research in France, 71% in the USA and 79% in Japan [15]. Biotechnology investments concentrated in high-income countries are also in private sector interests. Only 20% of the investments in biotechnology are from the public sector, with the rest coming from the private sector [16].

### Global biotechnology

Here we summarise biotechnology activities from countries around the world (Table 1).

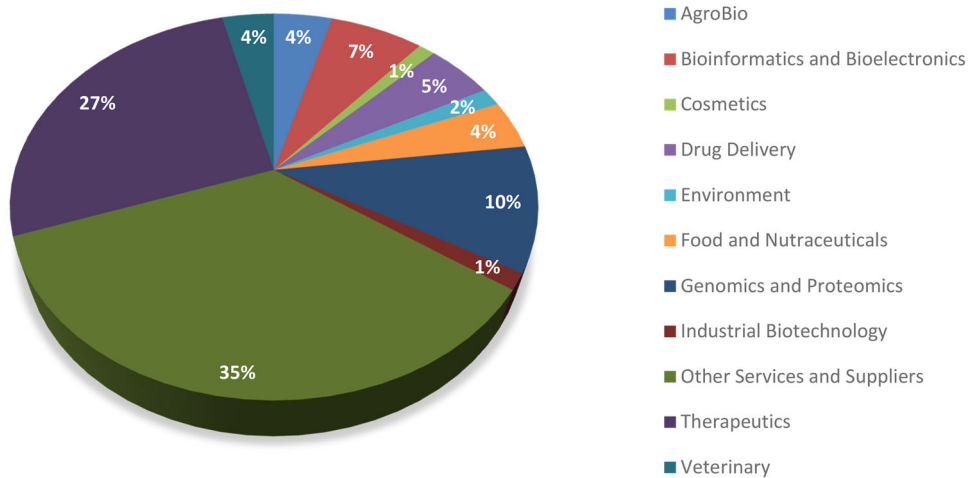


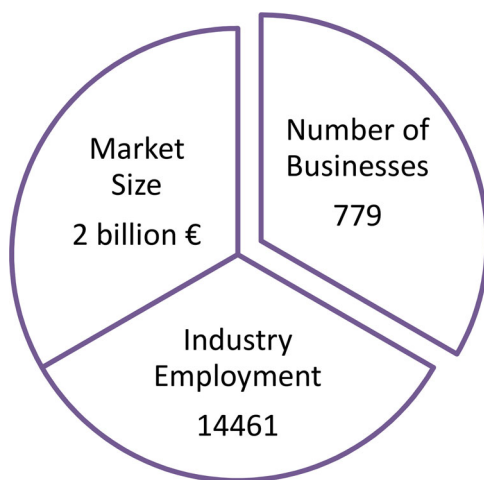
Figure 7. Percentage representation of UK Biotech companies [32].



Figure 8. Market sizes, number of enterprises and employment in the biotechnology sector of the USA, Australia and UK in 2019.

The average growth rate of biotechnology in Australia was 2.3% in the 5-year period between 2015 and 2020. The Australian Biotech industry is predicted to continue growing over the next five years due to increased demand and greater acceptance of biotech products. As a result, it is anticipated that the industry will generate income from a broader range of resources [29].

China has made progress in biotechnology in terms of competence and knowledge, although being well below the technology frontier in the early twenty first century. China also specialized in industrial-biotechnology and companies have played a significant critical role in the development of biotechnology in this field.

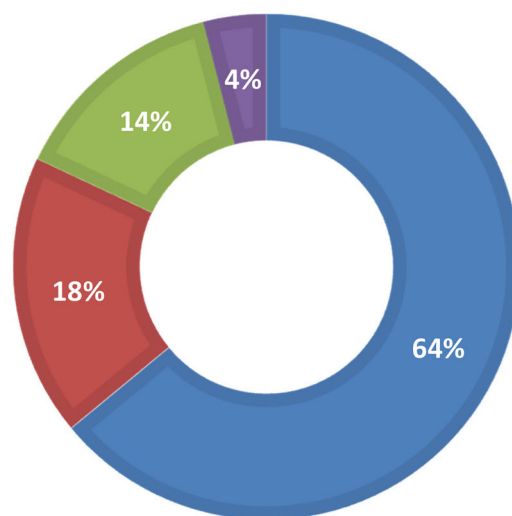


**Figure 9.** Market size, number of biotechnology enterprises and employment in the biotechnology sector in Germany in 2018.

The Chinese State Council has published the “Medium and Long Term Science and Technology Development Program (2006–2020)”, which aimed to promote innovation in 2006. With this 15-year plan, a national strategy to encourage the development of local innovation has been created and Biology has been added to the list as a priority area supported by the state in financial terms. China’s National Development and Reform Commission announced the “11th five-year plan” in July 2007 to gain speed in the development of China’s new technologies in the fields of bio-medicine, bio-agriculture, bio-energy, bio-manufacturing, bio-industry and bio-environmental protection. Five years later, the 12th five-year plan was announced, and in line with these plans, China has made continuous progress in biotechnology areas such as basic research, applied research, technological transformation and industrial development [26].

The average sector growth rate in biotechnology in the USA between 2015 and 2020 is 0.8%. In the five years until 2020, there has been an increase in demand for genetically modified seeds. It is predicted that the studies in agricultural biotechnology will continue unabated until 2025. In addition to agricultural biotechnology, it continues in biotechnological studies in the field of health. Figure 6 shows the biotechnology market size of the USA in the 10-year period between 2010 and 2020 [30].

The average sector growth rate in biotechnology in the UK between 2015 and 2020 is 6.9%. Medicine and medical technology are developing rapidly in the UK. Biotechnology industry revenue is expected to



■ Bio-Pharma ■ Industrial Biotechnology ■ Bio-Agriculture ■ Others

**Figure 10.** Biotechnology industry shares in India (2019).

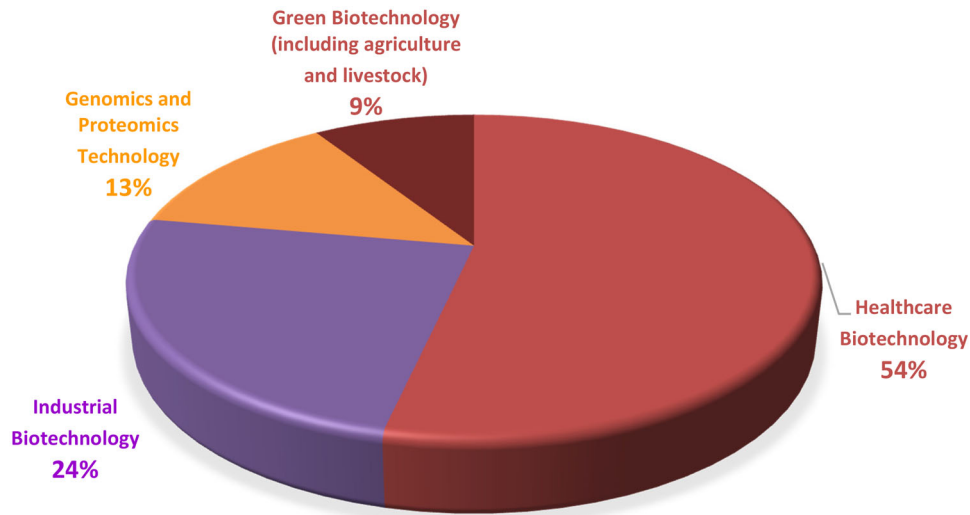


Figure 11. Italian biotech market (2016) [37].

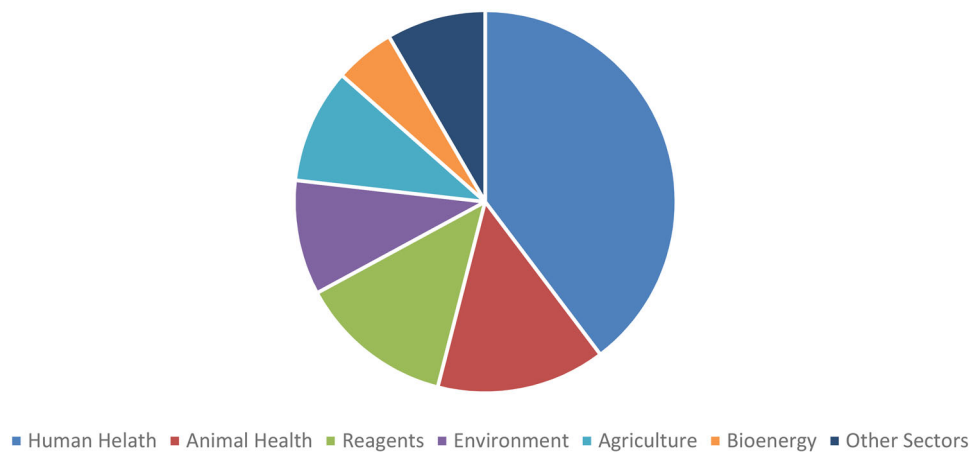


Figure 12. Distribution of Brazilian biotech companies (2017) [38].

increase by 6.7% from 2020 to 2021 to 13.8 billion euros. After Britain's exit from the European Union, the government has a focus on the science and research industries to drive the economy. Increasing government investments in research and development (R&D) are expected to be particularly beneficial in the coming years [31]. In 2019, the total number of biotech companies in the UK was 996. The distribution of UK biotechnology companies across the various sectors is shown in Figure 7 [32].

The market sizes, the number of enterprises and the number of employees in the biotechnology sector of the USA, Australia and UK in 2019 are compared in Figure 8.

The average sector growth rate in biotechnology was 10% in Germany during the period between 2013 and 2018. Studies conducted in the field of biopharmaceuticals have increased significantly in the last five years. This has led to a significant increase in the

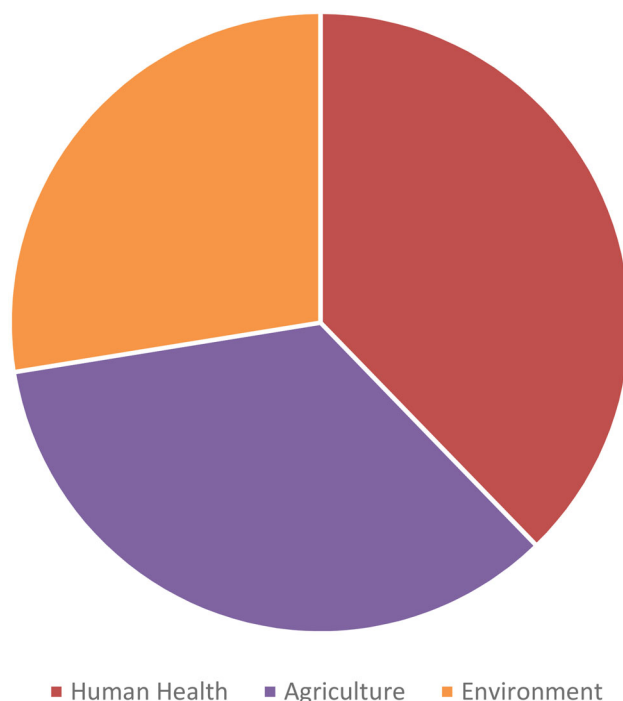
revenue generated by biopharmaceuticals and the market share in the pharmaceutical market. In addition to biotechnological studies in the pharmaceutical sector, environmental biotechnology and industrial biotechnology are among the biotechnological studies in Germany [33]. The market size, biotechnology enterprises and employment numbers in the biotechnology sector in Germany in 2018 are shown in Figure 9.

India ranks among the top 12 countries in the biotech industry in the world, with an approximate 3% share in the global biotech industry. India is also a leader in the worldwide supply of tuberculosis and measles vaccines. The biotech industry in India consists of more than 2,700 biotech startups and is expected to grow to 10,000 by 2024. There are more than 2,500 Biotechnology companies in India. The Indian biotech industry, which was worth 64 billion dollars in 2019, is expected to reach its target of 150 billion dollars by 2024–25. The biotechnology sector in



India is divided into three main sections as pharmaceutical biotechnology, agriculture, and industrial biotechnology. While the biopharmaceutical sector has the largest share of the biotechnology industry, with 64% of the total revenues, it is followed by industrial biotechnology with 18% and bio-agriculture with 14% [34]. This distribution is shown in Figure 10.

In Italy, the value of the biotechnology industry has increased with the developing technology as well as



**Figure 13.** The distribution of biotechnology companies in Turkey (2019) [39].

academic and industrial research in recent years. The number of Italian biotech companies reached 641 in 2018, and the turnover increased by 16% between 2014 and 2018, exceeding 13.6 billion dollars. With approximately 4,317 employees in biotechnology research, R&D investments have reached 2 billion dollars. As in other countries, biotechnology is more developed in the fields of medicine and health in Italy, compared to other sectors, and constitutes 320 of 641 biotechnology companies in total [35]. The total revenue of the Italian biotech market in 2019 was 13.5 billion dollars, representing a growth of 11.8% between 2015 and 2019 [36]. The distribution of the Italian biotechnology market for the various sectors in 2016 is given in Figure 11 [37].

According to a study conducted by CEBRAP (Centro Brasileiro de Análise e Planejamento/Brazilian Analysis and Planning Center) in 2017, there were 237 biotechnology companies in Brazil. The same year, according to SINDUSFARMA (Sindicato da Indústria de Produtos Farmacêuticos no Estado de São Paulo/Pharmaceutical Products Industry Syndicate in the State of São Paulo), Brazil's biopharmaceutical and biotech market turnover was approximately 18 billion dollars. The sectoral distribution percentages of 237 biotechnology companies are shown in Figure 12 [38].

Turkey is a country that is working to improve the development and progress in the field of biotechnology. Between 2016 and 2019, the number of businesses involved in biotechnological research increased. In 2019, 1692 people worked in biotechnology activities and the total R&D expenditure in these activities was approximately 325 million TL in the same year. This cost comprises 1.10% of the total total R&D

**Table 2.** Top 5 most productive institutions in terms of publications in the field of biotechnology (2019).

Contributor Institution	Publication count* (% of total)	Citations/ publication
French National Center for Scientific Research (CNRS)	236 (1.9%)	3.6
Chinese Academy of Sciences	216 (1.7%)	3.6
University of California system	214 (1.7%)	4.6
Spanish National Research Council (CSIC)	204 (1.7%)	4.4
University of São Paulo	177 (1.4%)	2.6

\*Note: The publication count is given as a percentage of the total numbers of biotechnology publications indexed in the WoS for the years 2017 to 2019, as described by Yeung *et al.* in reference [41].

**Table 3.** Top 5 most productive countries/regions in terms of publications in the field of biotechnology (2019).

Contributor Country/Region	Publication count (% of total)*	Citations/ publication
The United States of America	2,208 (17.9%)	3.9
China	1,559 (12.6%)	3.3
Germany	1,056 (8.6%)	3.6
Brazil	862 (7.0%)	2.0
India	756 (6.1%)	2.8

\*Note: The publication count is given as a percentage of the total numbers of biotechnology publications indexed in the WoS for the years 2017 to 2019, as described by Yeung *et al.* in reference [41].

expenditures. The sectoral distribution of 363 biotech startups in 2019 is shown in Figure 13 [39].

### Biotechnology research in the world

In the period between 2017 and 2020, it was reported that more than 12,000 articles were published in the world-wide biotechnology literature [40]. More than 8,500 institutions have contributed to those studies published worldwide in the field of biotechnology. The top five most productive institutions in this area are located in France, China, USA, Spain and Brazil (Table 2). Russia and Denmark follow them. More than 140 countries have also contributed to biotechnology research. The top five countries contributing to these studies are the USA, China, Germany, Brazil and India (Table 3). These distributions show how much weight has been given to studies in the field of biotechnology since 2017 [41]. Educating new generations of experts on the latest advances in the life sciences, as well as implementing other disciplines such as microfluidics and artificial intelligence [42, 43], are critical to fulfilling the promise of biotechnology for the success of endeavors to create a sustainable future.

### Conclusions

This short overview of global biotechnology demonstrates that biotechnology impacts various industrial sectors. The worldwide growth rate of biotechnology between 2015 and 2020 was 1.3%. It is expected that the biotechnology sector will achieve a steady increase in the next five years and that more investments will be made in research and development (R&D) worldwide. The growth of biotechnology industries in Europe is the focus of professional organisations such as the European Biotechnology Thematic Network Association (EBTNA). EBTNA is a non-profit Association that has the objectives (i) to implement, consult or supervise programmes for the assessment of skills and knowledge in sciences with an emphasis on biotechnology; (ii) to undertake programmes concerning education, training and research, especially those concerning innovative approaches; (iii) to operate as a consultant or assessor in programmes concerning education and training; (iv) to provide certification of achievement when assessments have been carried out under appropriate conditions; (v) to co-operate with established professional or other associations in the furtherance of its objectives; and (vi) to extend the reach of all aspects of education in biotechnology beyond national borders.

### Disclosure statement and data availability

The authors have no potential conflict of interest. EBTNA is a non-profit organisation. This article was prepared without direct financial support. This article was prepared using publicly available data from published articles or websites.

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