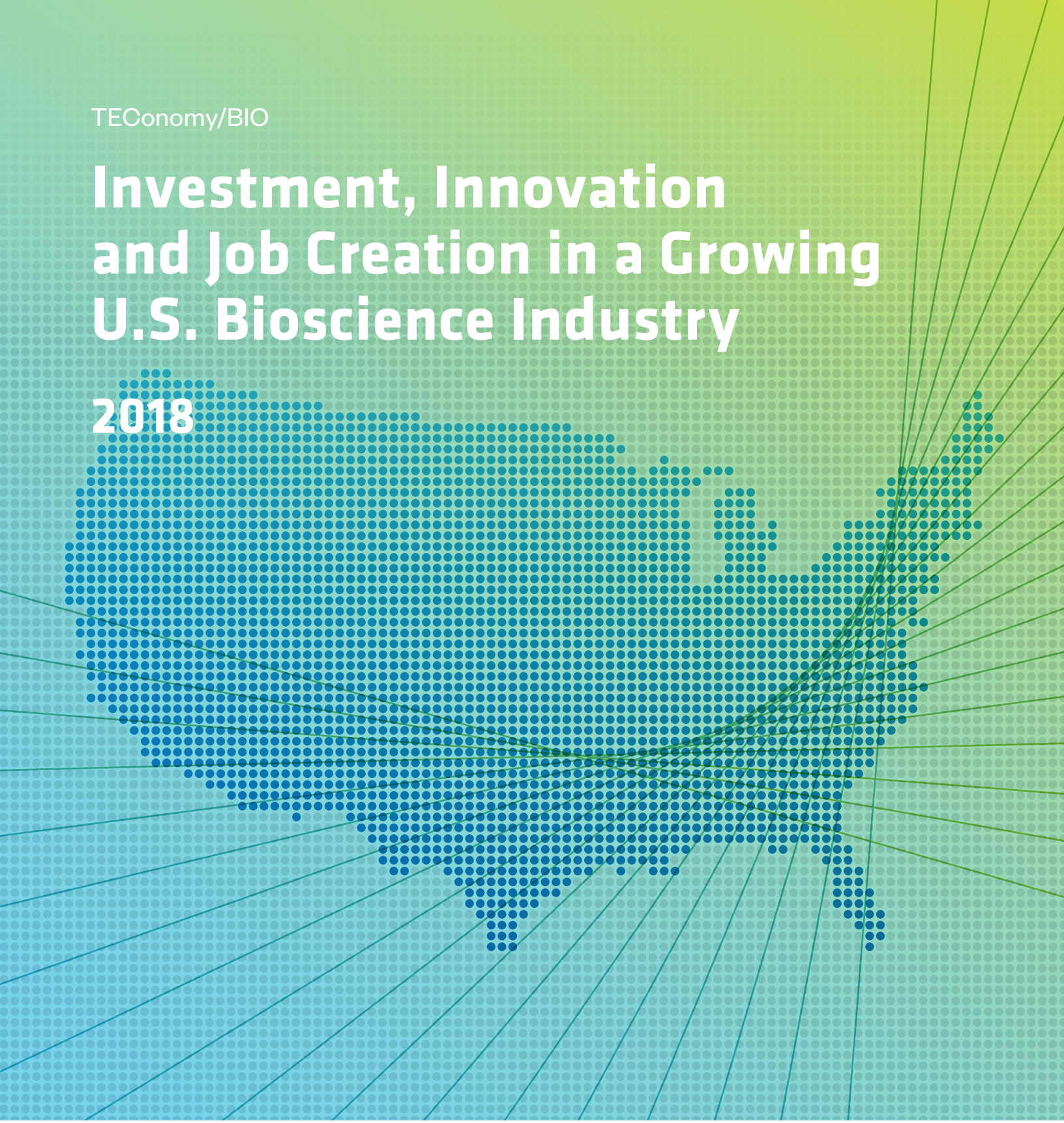
TEConomy/BIO

Investment, Innovation and Job Creation in a Growing U.S. Bioscience Industry

2018



TECONOMY PARTNERS LLC

Bio Biotechnology Innovation Organization

25 YEARS OF INNOVATION

BIO is the world's largest trade association representing biotechnology companies, academic institutions, state biotechnology centers and related organizations across the United States and in more than 30 other nations. BIO members are involved in the research and development of innovative healthcare, agricultural, industrial and environmental biotechnology products. BIO also produces the BIO International Convention, the world's largest gathering of the biotechnology industry, along with industry-leading investor and partnering meetings held around the world. BIOtechNOW is BIO's blog chronicling "innovations transforming our world."

TEConomy Partners, LLC is a global leader in research, analysis and strategy for innovation-based economic development. Today we're helping nations, states, regions, universities and industries blueprint their future and translate knowledge into prosperity. The principals of TEConomy Partners include the authors of the prior Battelle/BIO State Bioscience Development reports, published since 2004. For further information, please visit www.teconomypartners.com.

PMP Public Affairs Consulting, Inc.—PMP— is an independent consulting firm serving the public and constituent relations needs of bioscience-related companies and associations.

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INTRODUCTION AND HIGHLIGHTS

The bioscience industry represents the unique confluence of key characteristics for societal and economic progress—extremely high levels of innovation that are saving and improving lives through advancements in biomedical, energy and advanced food and industrial technologies; and expanding a wide mix of employment opportunities with wages and incomes that support a high standard of living. The industry thinks big and is addressing a host of global grand challenges related to diagnosing, treating and curing disease; ensuring a safe, affordable and more sustainable food supply; and leveraging biotechnologies and sustainable approaches to develop biobased fuels, chemicals and other industrial products.

This eighth, biennial report focuses on the economic progress and footprint of the industry geographically including the performance, positioning and latest trends in the bioscience industry for the nation, states and metropolitan areas. For the first time, it includes a national assessment of the full economic impact of the bioscience industry not only in terms of employment, but also with respect to economic output and fiscal impacts. In addition, the report details the situation for the industry's innovation ecosystem considering several key facets that ensure a high-performing industry and the long-term success it has maintained. These include the nation's academic research activities and trends in federal funding, access to critical angel and venture capital and the innovation outputs context via patent activities.

This report, and the accompanying state profiles made available online, continues to focus on the activities and economic benefits across states, as the bioscience industry has an extensive economic reach and impacts that benefit every region of the country.

National Industry Highlights

The following are highlights and key findings from the latest TEConomy/BIO industry assessment:

- The U.S. bioscience industry directly employed 1.74 million in 2016 in more than 85,000 business establishments.
- Since 2001, U.S. bioscience companies have increased employment by 273,000 jobs, or nearly 19 percent, with net job gains recorded by the industry in all but 2 of the last 15 years.

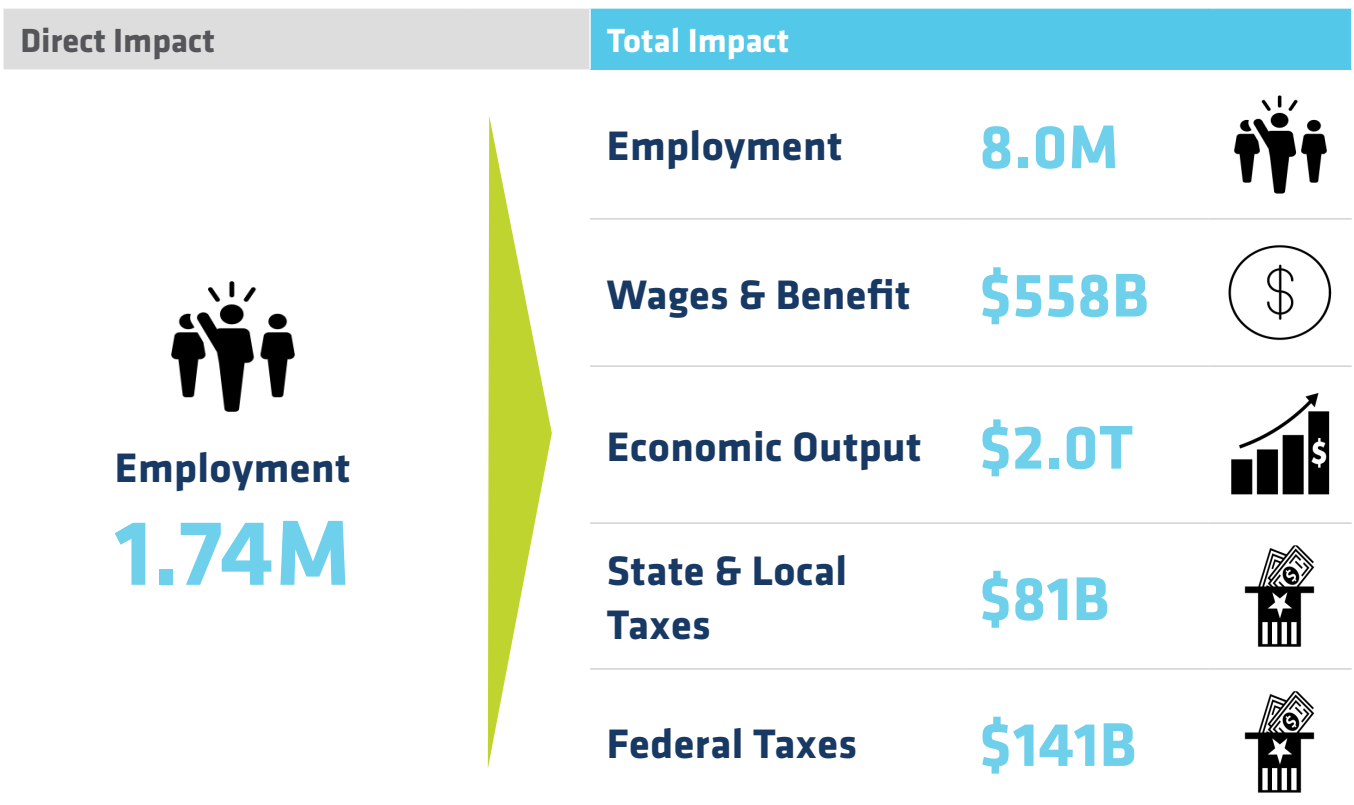
- Since 2014, total bioscience industry employment has risen by 4.4 percent, with four of the industry's five major subsectors contributing to the job gains. Industry hiring accelerated in 2015 and 2016 compared with the prior two years.

- Bioscience industry wages are consistently higher and growing faster, on average, than those for the overall economy, reflecting the skilled, high-quality jobs in demand. The average U.S. bioscience worker earned nearly $99,000 in 2016, 85 percent greater than the average for the overall private sector.

- The bioscience industry's total economic impact on the U.S. economy, as measured by overall output, totaled $2 trillion in 2016 (Figure 1). This impact is generated by the direct output of the bioscience industry combined with the indirect (supply chain) and induced (employee spending) impacts.

- The industry's 1.74 million employees and its associated economic output support 8 million jobs throughout the entire U.S. economy through both indirect and induced effects.

Figure 1
Economic Impacts of the U.S. Bioscience Industry, 2016



Source: TEConomy Partners data, analysis using IMPLAN U.S. Input/Output Model, 2016.

State-by-State and Metropolitan Area Bioscience Industry Highlights

The nation's bioscience industry extends to every state, and a majority have a specialized concentration of jobs in at least one bioscience subsector. In fact, the number of states with a niche industry specialization has increased from 32, two years ago, to 38 today. Likewise, the industry is an important economic engine for the nation's metropolitan regions.

- Thirty-eight states and Puerto Rico have a specialization in at least one of the five bioscience subsectors in 2016. These include:
  - 18 states specialized in Agricultural Feedstock & Industrial Biosciences
  - 11 states and Puerto Rico specialized in Bioscience-related Distribution
  - 12 states and Puerto Rico specialized in Drugs & Pharmaceuticals
  - 14 states and Puerto Rico specialized in Medical Devices & Equipment
  - 11 states and Puerto Rico specialized in Research, Testing & Medical Laboratories

- Over the 2014 to 2016 period, 41 states experienced job growth in the bioscience industry.

- The industry is well distributed across the nation's metropolitan areas with 213 of the nation's 383 metro regions (nearly 56 percent) having a specialized employment concentration in at least one bioscience subsector.

- Twenty-six metro regions have a specialized concentration in at least three bioscience subsectors. These local areas span every region of the country and are varied in size.

Innovation Ecosystem: Key Findings

Performance and trends in the national ecosystem for biosciences development have been quite positive, however continued national and state support for industry innovation is critical for maintaining national competitiveness. Highlights from the ecosystem assessment include:

- **Venture Capital Investments in the Biosciences Reach New Highs.** More than $66 billion in venture capital was invested in bioscience companies in the 2014 through 2017 period. It is common to see year-to-year variability in the levels of investments, but there has been an upward trend in industry investing with new highs reached in the biosciences in 2015 (at $17.0 billion) and then again in 2017 when $20 billion was invested.
- **Ecosystem Bolstered by Increasing NIH Budgets.** For several years, concerns have been raised regarding declining and/or flat NIH research budgets and the subsequent effects on academic and other research. Fortunately for the bioscience community, NIH funding is back on the rise with budget increases sustained each of the last three years.
- **Growth for Academic Biosciences R&D in 2016.** Following a 1.5 percent decline in 2015, academic R&D expenditures in the biosciences increased a healthy 5.5 percent to $42 billion in 2016.
- **Patent Activity Reflects Expanding Innovation.** The U.S. has increased patent totals in bioscience-related technology classes by nearly 5 percent since 2014, or 1.6 percent per year, on average. While 2015 and 2016 had lower numbers of total patents awarded to a U.S. inventor, 2017 saw the total rise to nearly 27,000, a new high.

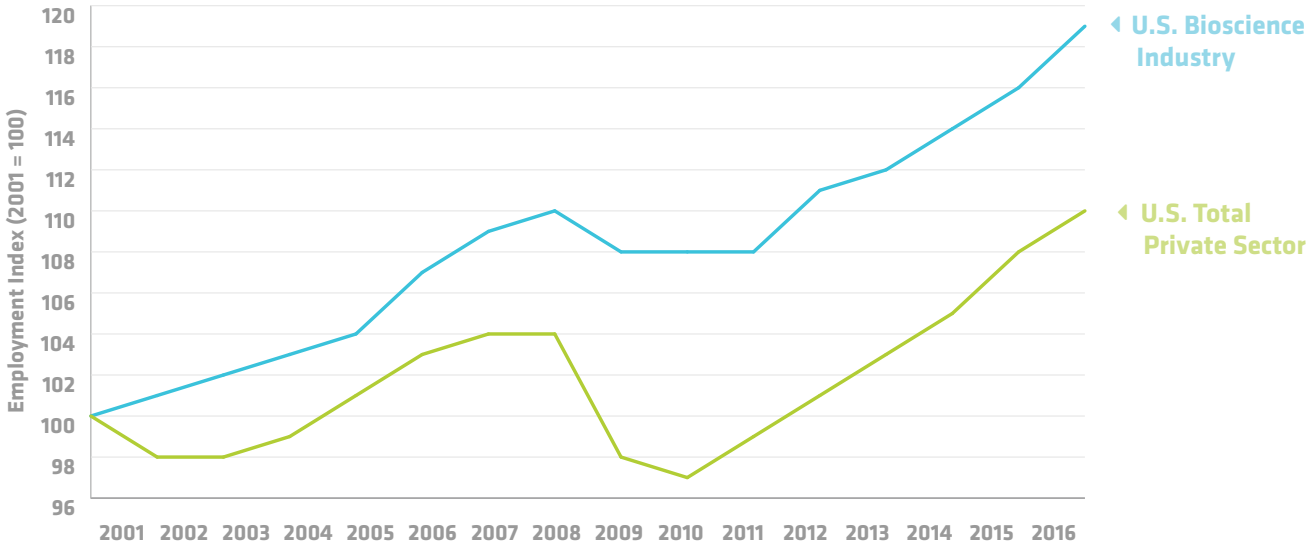
U.S. BIOSCIENCE INDUSTRY CONTINUES LONG-TERM GROWTH TREND

The nation's bioscience industry is continuing to generate high-quality jobs at a steady pace. More than 6 years into the current economic expansion, employment among industry firms reached 1.74 million jobs in 2016 across a diverse array of industry subsectors operating at nearly 86,000 U.S. business establishments.

Since 2001, U.S. bioscience companies have increased employment by 273,000 jobs, nearly 19 percent, with net job gains recorded by the industry in all but 2 of the last 15 years (Figure 2). The industry has been less affected by recessions compared with the rest of the economy and this

Figure 2

U.S. Bioscience Industry and Private Sector Employment Trends, 2001-16



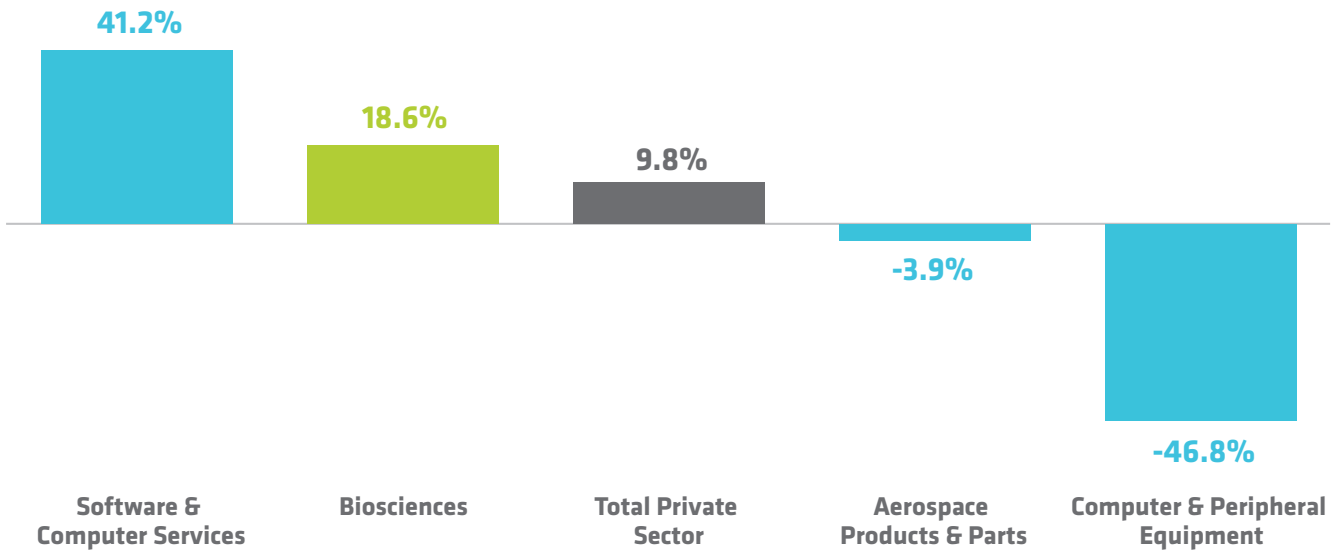
Source: TEConomy Partners analysis of U.S. Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

resilience meant that during the Great Recession the biosciences did not contract as deeply as the nation's overall private sector. Additionally, the bioscience industry was able to regain its footing and recover its lost jobs much faster than the economy as a whole. Industry job growth has accelerated during the current expansion—its average annual growth has risen by 0.2 percentage points compared with the average for the 2001-2008 period.

Looking back over a decade and a half, this knowledge-based and technology-driven industry represents the confluence of two key characteristics for societal and economic progress—extremely high levels of innovation that are saving and improving lives through advancements in biomedical, energy and advanced food and industrial technologies; and expanding a mix of employment opportunities with wages and incomes that support a high standard of living. Its long-term performance compares well against other major U.S. technology industries with job gains nearly twice that of the overall private sector and behind only software and computer services among other leading technology sectors (Figure 3). While not matching the rapid rate of growth in software and computer services, the biosciences are increasingly overlapping and converging with information technologies involving a wide range of expanding applications in areas such as electronic medical records, connected devices for patient monitoring, bioinformatics, precision agriculture and other uses of information technologies for improving diagnosis, targeting treatments and improving healthcare delivery.

The bioscience industry's physical footprint includes 85,702 establishments owned and operated by industry firms across every U.S. state. Since 2001, the bioscience industry has increased business establishments by 40 percent compared with just under 19 percent for the overall private sector. In

Figure 3
Employment Change—the U.S. Bioscience Industry vs. Other Technology Industries, 2001-16



Source: TEConomy Partners analysis of U.S. Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

Defining the Biosciences

Defining the biosciences is challenging due to its diverse mix of technologies, products, R&D focus and companies themselves. The industry includes companies engaged in advanced manufacturing, research activities and technology services but has a common thread or link in their application of knowledge in the life sciences and how living organisms function. At a practical level, federal industry classifications don't provide for one over-arching industry code that encompasses the biosciences. Instead, two dozen detailed industries must be combined and grouped to best organize and track the industry in its primary activities.

The TEConomy/BIO State Initiatives reports have developed an evolving set of major aggregated subsectors that group the bioscience industry into five key components, including:

Agricultural feedstock and industrial biosciences —Firms engaged in agricultural production and processing, organic chemical manufacturing and fertilizer manufacturing. The subsector includes industry activity in the production of ethanol and other biofuels.

Bioscience-related distribution —Firms that coordinate the delivery of bioscience-related products spanning pharmaceuticals, medical devices and ag biotech. Distribution in the biosciences is unique in its deployment of specialized technologies including cold storage, highly regulated monitoring and tracking and automated drug distribution systems.

Drugs and pharmaceuticals —Firms that develop and produce biological and medicinal products and manufacture pharmaceuticals and diagnostic substances.

Medical devices and equipment —Firms that develop and manufacture surgical and medical instruments and supplies, laboratory equipment, electromedical apparatus including MRI and ultrasound equipment, dental equipment and supplies.

Research, testing and medical laboratories —Firms engaged in research and development in biotechnology and other life sciences, life science testing laboratories and medical laboratories. Includes contract and clinical R&D organizations.

It is important to note that in the federal data used for the industry assessment a bioscience company operating multiple U.S. establishments can be classified into more than one industry subsector depending upon the primary activity of each individual establishment. For example, a company establishment focused on R&D would be classified within research, testing and medical labs while that same company's distribution facility would be classified within the distribution subsector.

For this edition of the biennial report, TEConomy and BIO re-examined the industry definition to understand and explore whether additional industries are worthy of inclusion and in particular, examined industries active in the industrial and agricultural biosciences. And while there is extensive emerging activity in these sectors, the NAICS codes in which these companies reside are still not "primarily" bioscience in nature. See the feature on Industrial Biotechnology and the Biobased Economy on page 14 of this report for more.

the recent 2014 to 2016 period, the bioscience industry grew its establishment base by 7.7 percent compared to 3.4 percent private sector growth. The average bioscience establishment employs more than its counterparts in the overall private sector—an average of 20 jobs per bioscience establishment compared with 13 jobs in the private sector.

Recent Industry Performance: Job Growth Accelerates in 2015-16

While stepping back to re-examine this longer-term track record provides important perspective, this 2018 edition of the TEConomy/BIO biennial report focuses on the more recent past, with the primary focus of the national and state-level data and performance analysis for the industry and its innovation ecosystem from 2014 through 2016. And in the case of some data, the analysis extends through 2017.

To best understand the industry's performance and dynamics, it is important to look to the diverse components that form the industry. Since 2004, this biennial report has defined and organized the industry across a set of major "subsectors" utilizing federal industry classifications that combine to form as complete a definition as possible (recognizing the constraints of these industry classifications) and one that is comparable for an assessment across states and even metropolitan regions. Five major subsectors form the industry definition today:

- Agricultural Feedstock & Industrial Biosciences
- Bioscience-related Distribution
- Drugs & Pharmaceuticals
- Medical Devices & Equipment
- Research, Testing & Medical Laboratories

Table 1
U.S. Bioscience Establishment and Employment Data, 2016 and Percent Change, 2001-16 and 2014-16

Bioscience Industry & Subsectors	Establishment Data			Employment Data		
	Count, 2016	Change, 2001-2016	Change, 2014-2016	Count, 2016	Change, 2001-2016	Change, 2014-2016
Agricultural Feedstock & Industrial Biosciences	1,709	2.8%	-3.2%	68,027	-1.3%	-1.2%
Bioscience-related Distribution	39,149	7.0%	3.8%	469,640	13.1%	3.7%
Drugs & Pharmaceuticals	3,754	44.0%	13.7%	299,113	-2.0%	2.0%
Medical Devices & Equipment	8,083	29.7%	5.9%	359,293	4.3%	2.9%
Research, Testing & Medical Laboratories	33,007	133.3%	13.1%	547,566	62.7%	8.2%
Total Biosciences	**85,702**	**40.0%**	**7.7%**	**1,743,639**	**18.6%**	**4.4%**

Source: TEConomy Partners analysis of U.S. Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

Subsector performance/overviews

Research, testing and medical laboratories is the largest and fastest growing among the bioscience industry subsectors since 2014. The subsector is unique relative to the others in its service offerings for contract and clinical research expertise. Subsector firms employ more than 547,000 or 31 percent of the overall bioscience industry and have an impressive record of net job gains on an annual basis as far back as 2001. Since 2014, both components of the subsector have grown but the biotechnology and other life sciences R&D employment has been faster, increasing nearly 10 percent compared with about 4 percent growth for medical labs.

Bioscience-related distribution employed nearly 470,000 in 2016 across a widespread national geographic footprint that spanned more than 39,000 business establishments. The subsector's 3.7 percent job growth since 2014 was primarily driven by its two largest components—medical, dental and hospital equipment and supplies distribution (up nearly 5 percent) and the delivery of drugs and pharmaceuticals (up 4 percent). The subsector accounts for 27 percent of national bioscience employment.

Medical device and equipment companies employ more than 359,000 and have grown their employment base by 2.9 percent since 2014, an acceleration of job growth after several years of relatively flat employment levels. The subsector, which employs one in five bioscience workers, had most of its job gains since 2014 in the electromedical apparatus component, which includes a wide range of product manufacturing including MRI equipment and PET scanners as well as pacemakers and endoscopic equipment.

Drugs and pharmaceuticals has seen a 2 percent employment gain since 2014 with subsector jobs totaling more than 299,000 in 2016. In fact, following several years of net job losses, the subsector has experienced four consecutive years of at least some net job increase. The subsector is not only growing jobs but also its business establishments which outpaced rapid growth industry-wide, boosting its physical footprint by 13.7 percent. Jobs in drugs and pharmaceuticals have the highest average wages among the major subsectors, reaching nearly $114,000 in 2016. Two components of the subsector had double-digit job growth from 2014 through 2016—biological products, which includes vaccines and gene therapies among other products and medicinal and botanical manufacturing. While drugs and pharmaceuticals accounts for 17 percent of U.S. bioscience jobs, the subsector is closely aligned with R&D establishments that fall within research, testing and medical labs, as well as within bioscience-related distribution.

Agricultural feedstock and industrial biosciences employs more than 68,000 nationally in more than 1,700 business establishments. The subsector had a 1.2 percent employment decline from 2014 through 2016 with modest job losses spread across the agricultural chemicals components. The job declines were partially offset by gains among the agricultural feedstock components including wet corn milling and oilseed processing. Despite the recent job declines, subsector employment has risen by 2.9 percent during the economic expansion (since 2010). The contraction of subsector establishments may be linked to recent consolidation within the industry.

Since 2014, total bioscience industry employment has risen by 4.4 percent, with four of the five major subsectors contributing to the job gains (Table 1). Industry hiring accelerated in 2015 and 2016 compared with the prior two years, averaging 2.2 percent annually compared with 1.3 percent annually in 2013-14.

Research, testing and medical labs, the largest of the industry subsectors, led with 8.2 percent job growth from 2014 to 2016, and continues its impressive record of consistently adding jobs every year back to 2001. Following two years of slower growth, drugs and pharmaceuticals hiring accelerated in 2016. Similarly, after several years of smaller gains and one modest decline, medical device manufacturing had 1.5 percent annual growth in both 2015 and 2016. Firms in the bioscience distribution space also increased their pace in hiring during the recent two-year period by 3.7 percent. Agricultural feedstock and industrial biosciences is the only subsector to see a modest decline, with employment decreasing by less than 1 percent each of the last two years.

Bioscience Wages: Rising Wages and Expanding Wage Premium for Industry Workers

The bioscience industry stands out for being a generator and source of high-wage jobs. Industry wages are consistently higher and growing faster, on average, than those for the overall economy. This reflects the skilled, high-quality jobs in demand within an industry advancing a wide range of value-adding products and services, and it further reflects the importance of the industry as a national economic engine.

In 2017 the nation's bioscience workers earned nearly $99,000, on average (Table 2), which is more than $45,000 (85 percent) above the average for the nation's private sector. This wage premium earned by bioscience workers has grown from 64 percent in 2001 to 85 percent today.

Each bioscience subsector has average wages well above those for the overall private sector, as well as exceeding those for most other major U.S. industries. Employees within both the drugs and pharmaceuticals and research, testing and medical labs subsectors earn average wages exceeding $100,000 annually, higher than for their counterparts in industries such as finance and insurance and information.

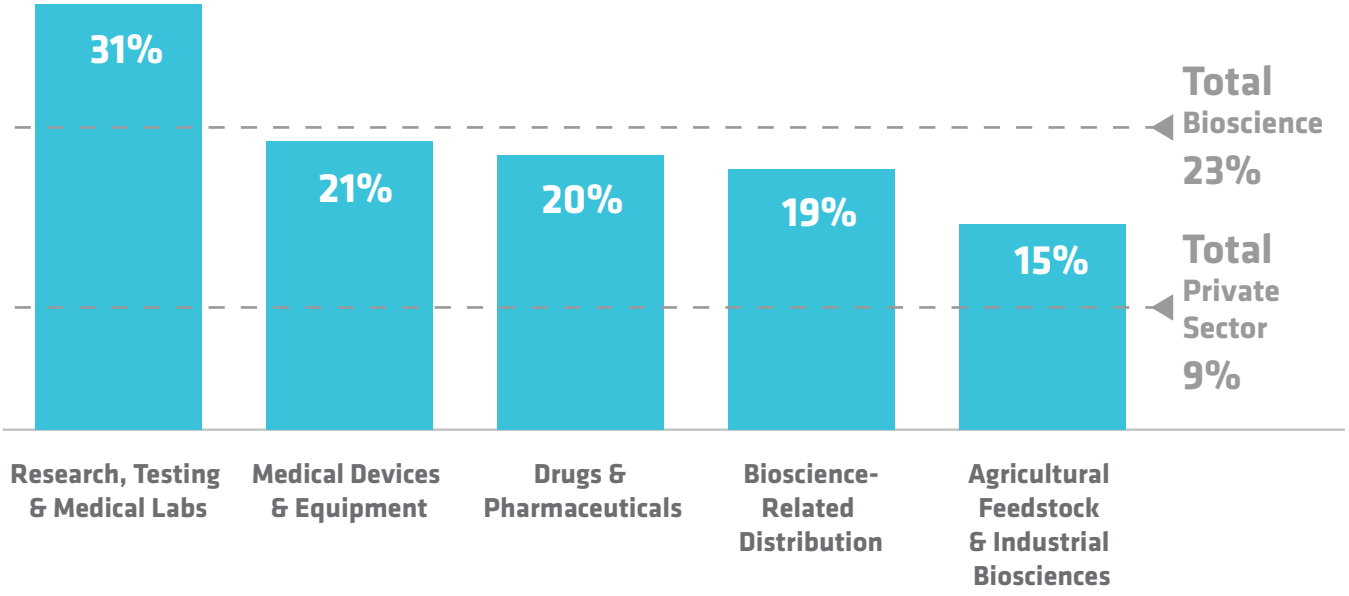
Table 2

Average Annual Wages for the Biosciences and Other Major Industries, 2016

Employment Sector	Annual Average Wage
Drugs & Pharmaceuticals	$113,815
Research, Testing & Medical Labs	$106,942
Finance & Insurance	$101,180
Total Biosciences	**$98,961**
Information (IT, Telecommunications, Broadcasting, Data Processing)	$98,475
Bioscience-Related Distribution	$93,677
Professional & Technical Services	$90,950
Medical Devices & Equipment	$84,746
Agricultural Feedstock & Industrial Biosciences	$80,961
Manufacturing	$64,860
Construction	$58,643
Real Estate & Rental & Leasing	$54,959
Total Private Sector	**$53,354**
Transportation & Warehousing	$50,443
Health Care & Social Assistance	$47,955
Retail Trade	$30,297

Source: TEConomy Partners analysis of U.S. Bureau of Labor Statistics, QCEW data; QCEW data; enhanced file from IMPLAN.

Figure 4
Change in Real Average Annual Wages in the Biosciences and the Total Private Sector, 2001-16



Source: TEConomy Partners analysis of U.S. Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

Long-term average wage growth for the biosciences has outpaced that for the private sector. Since 2001, real (inflation-adjusted) wages have increased by 23 percent versus just 9 percent for the economy as a whole (Figure 4). Workers in each of the major subsectors have seen their average wages rise by double-digits over the decade and a half, with those in research, testing and medical labs experiencing the greatest increase (up 31 percent).

Economic Impacts: The Bioscience Industry's Broader Value and Contributions to the National Economy

The bioscience industry's 1.74 million workers earning high wages and developing, manufacturing and distributing innovative products and services across every U.S. state, create a substantial national economic impact. Like other industries, the biosciences have an extensive, interdependent supply chain for inputs to research, production and distribution activities. The industry both supports and depends upon other companies and industries to supply everything from business services to commodity inputs. In addition, industry employees generate demand for goods and services through their personal spending. As a result, the biosciences have a national economic impact that extends well beyond their direct employment and earnings.

Economic impact analysis using Input/Output models measures the types of impacts and effects described, including:

- **Direct effects:** the direct employment and other economic activity generated by the industry's operations and expenditures;
- **Indirect effects:** the economic activity generated for supplier firms by the target industry; and

- **Induced effects:** the additional economic activity generated by the personal spending of the direct employees and the employees of the supplier firms in the overall economy.

The sum of these three effects is referred to as the total economic impact. TEConomy estimated the total economic impact of the U.S. bioscience industry in 2016 based on employment values for each detailed industry sector within the biosciences and evaluated the impacts across several key economic measures:

- **Employment.** The total number of full- and part-time jobs in all industries;
- **Personal Income.** The wages and salaries, including benefits, earned by the workers holding the jobs created;
- **Value-Added.** The difference between an industry's total output and the cost of its labor and other inputs; and
- **Output.** The total value of production or sales in all industries. [1]

Additionally, the model allows for a high-level estimation of tax revenues generated by the economic activity at a combined state/local level and at a federal level. These tax revenues include estimates of a variety of corporate and personal tax payments, including both the employer and employee portions of social insurance taxes.

The bioscience industry's total economic impact on the U.S. economy, as measured by overall output, totaled $2 trillion in 2016 (Figure 5 and Table 3).

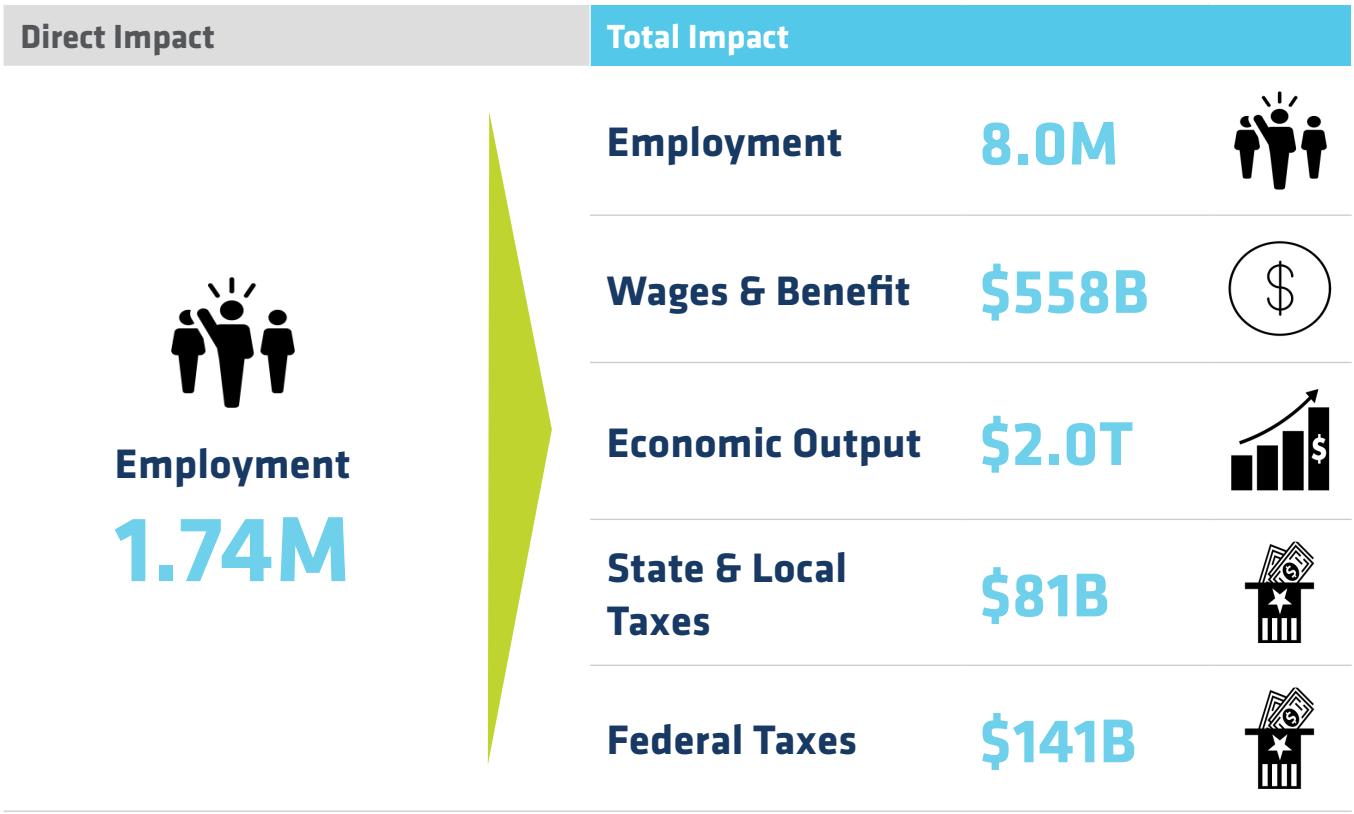
This impact is generated by the direct output of the bioscience industry which totaled $885 billion combined with the indirect and induced impacts that total more than $1.1 billion. This means every $1 in industry output generates an additional $1.27 in output throughout the rest of the national economy, for an industry output "multiplier" of 2.27. This substantial industry output represents 6.1 percent of all U.S. economic activity.

The industry's 1.74 million employees and its associated economic output support 8 million jobs throughout the entire economy through both indirect and induced effects. These additional jobs span numerous other industries including those in the supply chain such as real estate, consulting, legal services, transportation, information technology and utilities, just to name some. The industry's employment multiplier is 4.57, meaning that for every bioscience job an additional 3.57 jobs are supported throughout the rest of the national economy.

Additional economic impacts of the industry extend to its contributions to local, state and federal tax revenues through the corporate, personal income and other taxes paid by bioscience firms, their suppliers and their workers. These total taxes, through a combined direct and multiplier effects, are estimated to have contributed $81 billion to state and local governments and $141 billion to the federal government in 2016.

1 *In impact-related literature the total output impacts are often referred to as the "economic impact" of a project or investment.*

Figure 5
Economic Impacts of the U.S. Bioscience Industry, 2016



Source: TEConomy Partners data, analysis using IMPLAN U.S. Input/Output Model, 2016.

Table 3
Economic Impacts of the U.S. Bioscience Industry, 2016 ($ in millions)

Impact Type	Employment	Labor Income	Value Added	Output	State/Local Tax Revenue	Federal Tax Revenue
Direct Effect	1,743,639	$181,526	$422,520	$884,545	$27,418	$52,083
Indirect Effect	2,763,391	$201,634	$314,176	$574,249	$24,245	$46,063
Induced Effect	3,468,360	$174,993	$309,087	$549,423	$29,413	$42,921
Total Impact	**7,975,390**	**$558,153**	**$1,045,783**	**$2,008,218**	**$81,076**	**$141,068**
Multiplier	*4.57*	*3.07*	*2.48*	*2.27*		

Source: TEConomy Partners data, analysis of U.S. IMPLAN Input/Output Model, 2016.

Industrial Biotechnology and the Biobased Economy

Bioscience innovation at work expanding markets for sustainable industrial products, demonstrating commercial success, and presenting opportunities for U.S. companies and rural America to seize upon.

The authors of this report have long recognized the challenges of fully capturing and including all relevant bioscience-related industrial activities in a definition that is constrained by the limitations of federal industrial classifications (industry NAICS codes). The biosciences and biotechnologies have been at the leading edge of new product development and commercial markets within existing industries that government classifications often cannot isolate or stay ahead of. As a result, for comparable state-by-state comparisons, the industrial definition utilized in this report undoubtedly undercounts the full extent of bioscience-related activities.

One area where TEConomy has worked closely with BIO for this study is recognizing and examining the rising importance and economic contributions of the industrial biosciences, or the "biobased economy". Significant components of the biobased economy that are definable using NAICS codes are included within the TEConomy/BIO industrial definition, including certain feedstocks and ethanol production. However, much of the biobased activity is often captured within much larger, traditional petroleum-based product, agricultural production and other NAICS categories. For example, individual companies have had success with producing biobased plastics for a variety of applications (e.g., Polylactic Acid or PLA), but those specific companies are included among thousands of U.S. fossil fuel plastics producers. Within some sectors, TEConomy has been able to estimate national biobased employment and establishments, due to the availability of federal product-level data at a national, but not state level. These data, along with key findings from national and international assessments conducted by BIO, USDA and others are included here.

BIO defines the biobased economy as "the entire value chain of producing consumer goods from biological feedstocks and processes."[2] This value chain uses renewable resources or gases—such as biomass, algae or methane—as feedstock, instead of fossil fuel resources and is driven by increasing recognition of the need for, and value in, the sustainable sourcing of materials. The biobased economy is enabled by industrial biotechnology, a set of tools and technologies that leverage natural

The Biobased Economy

Source: Biotechnology Innovation Organization.

2 *Biotechnology Innovation Organization, "The U.S. Biobased Economy: Economic Impact" Fact Sheet, 2018.*

characteristics of microbes and enzymes as well as thermochemical processes via biorefining to translate biomass, carbon and biobased waste streams and off-gases into chemicals for industrial and consumer products.

Biobased products and applications are all around us and include transportation fuels, renewable specialty and commodity chemicals and power generation. Value-added renewable chemicals can be used to produce food, solvents, adhesives, cosmetics, personal care products and polymers for plastics and packaging.

The U.S. Department of Agriculture's BioPreferred® Program, developed with the goal of increasing market opportunities for biobased products, has commissioned studies to measure the economic impact of the renewable chemicals and biobased product industry's contribution to the U.S. economy. The most recent study[3] has included impacts through seven primary sectors:

- Agriculture and forestry
- Biorefining
- Biobased chemicals
- Enzymes
- Bioplastic bottles and packaging
- Forest products
- Textiles

The study for USDA found the biobased products industry contributed $393 billion in total value added and 4.2 million jobs to the nation's economy in 2014, when accounting for not only the direct industry contributions but also the "spillover" indirect and induced impacts. The USDA's figures do not count direct or indirect economic activity from biofuel production.

The industry's value chain originates from dedicated energy crops and operates through different types of biorefining approaches to produce industrial products and consumer goods that generate environmental, economic and other benefits. With agriculture at the heart of this materials sourcing comes numerous economic benefits and returns to rural America via existing and new markets and uses for agricultural products and rurally sourced biomass as feedstocks. Economic benefits to rural communities add to the overall value proposition for biobased industrial development through job creation.

> "Globally, the biotechnology sector is a driver of the 'fourth industrial revolution,' and presents an incredible opportunity for American farmers and rural communities to thrive at the forefront of innovation."
>
> *—USDA Task Force on Agriculture and Rural Prosperity, Report to the President of the United States*

The 2016 USDA study includes measuring the economic impacts to states, with leading states in direct employment reflecting top agricultural, chemical and other production states largely in the South and Midwest. The top 10 states in terms of direct jobs include: California, North Carolina, Texas, Georgia, Pennsylvania, Wisconsin, Ohio, New York, Alabama and Florida.

While technological and other developmental challenges remain—such as where to source biomass, further reducing processing costs and integrating products to consumers—the promise of industrial biotechnology and biobased products is exciting. The cost-competitiveness of biomass feedstocks, initial commercial successes of products, the prospects for novel performance characteristics of renewable chemicals and research investments underway point to accelerating growth opportunities. Lux Research estimates that venture capitalists invested $5.3 billion in biobased materials and renewable chemicals from 2010 through 2015.[4] BCC Research has a strong outlook for biobased products markets and

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3 United States Department of Agriculture, "An Economic Impact Analysis of the U.S. Biobased Products Industry," 2016.

4 Lux Research (2016). Show Me the Money: Where Is Venture Capital Placing Bets in Biobased? http://members.luxresearchinc.com/research/report/21604

opportunities, with expectations for 8.9 percent compound annual growth through 2021 projecting the global market for bioproducts to reach nearly $715 billion.[5]

TEConomy's analysis of biobased products' share of economic activity and corresponding national establishment and employment estimates within several industry NAICS classifications is presented below. These industries include both biobased and non-biobased products and several are emerging toward greater biobased products in a substantial manner. The total estimated biobased establishments and employment, just among these industries, total 292 and 15,835, respectively. TEConomy and BIO will continue to monitor these industry sectors and their embedded biobased production into the future for potential inclusion in the industrial biosciences definition used for state reporting.

Table 4

U.S. Biobased Product Share and Associated Establishments and Employment of Manufacturing Industries

NAICS Code	NAICS Title *Biobased Product Title*	Share of U.S. Establish-ments	Estimated Estabs. Assoc. with Biobased Products, 2016	Share of U.S. Employees	Estimated Employment Assoc. with Biobased Products, 2016
325194	**Cyclic crude, intermediate and gum and wood chemical manufacturing** *Gum/wood chemicals, incl. wood distillation products*	48%	43	44%	1,388
325199	**All other basic organic chemical manufacturing** *Total, all product codes below* *Fatty acids (produced for sale as such)* *Bulk pesticides and other bulk synthetic organic agricultural chemicals, excluding preparations* *Industrial organic flavor oil mixtures and blends* *Natural organic chemicals*	16%	122	17%	6,415
325220	**Artificial and synthetic fibers and filaments manufacturing** *Rayon, acetate and lyocell manufactured fibers*	9%	20	11%	2,820
325520	**Adhesive manufacturing** *Natural base glues and adhesives*	4%	27	6%	1,296
326150	**Urethane and other foam product (except polystyrene) manufacturing** *Products made of foam other than polystyrene or polyurethane, including phenolics, vinyl and cellulose acetate, etc.*	9%	80	11%	3,917

Source: TEConomy analysis of U.S. Census Bureau's Economic Census; Bureau of Labor Statistics, QCEW data.

Note: Other manufacturing industries were considered for this analysis and not included here as their biobased product categories were either not disclosed by the Census Bureau or the share of biobased activity was 1 percent or less.

5 *BCC Research, Biorefinery Products: Global Markets, March 2017.*

State-by-State and Metropolitan Area Bioscience Industry Key Findings and Highlights

The nation's bioscience industry extends to every state, with a well-distributed geographic presence. The importance of the industry as a job generator and economic driver is evident as a majority of states have a specialized concentration of jobs[6] in at least one bioscience subsector. In fact, the number of states with a niche industry specialization has increased from 32 two years ago to 38 today. Likewise, the industry is an important economic engine for the nation's metropolitan regions.

Highlights of state industry performance include:

- Thirty-eight states and Puerto Rico have a specialization in at least one of the five bioscience subsectors in 2016. These include:
  - 18 states specialized in Agricultural Feedstock & Industrial Biosciences
  - 11 states and Puerto Rico specialized in Bioscience-related Distribution
  - 12 states and Puerto Rico specialized in Drugs & Pharmaceuticals
  - 14 states and Puerto Rico specialized in Medical Devices & Equipment
  - 11 states and Puerto Rico specialized in Research, Testing & Medical Laboratories

- New Jersey and Puerto Rico stand out as the only states that are specialized in 4 of the 5 bioscience subsectors.

- Over the 2014 to 2016 period, 41 states experienced job growth in the bioscience industry.

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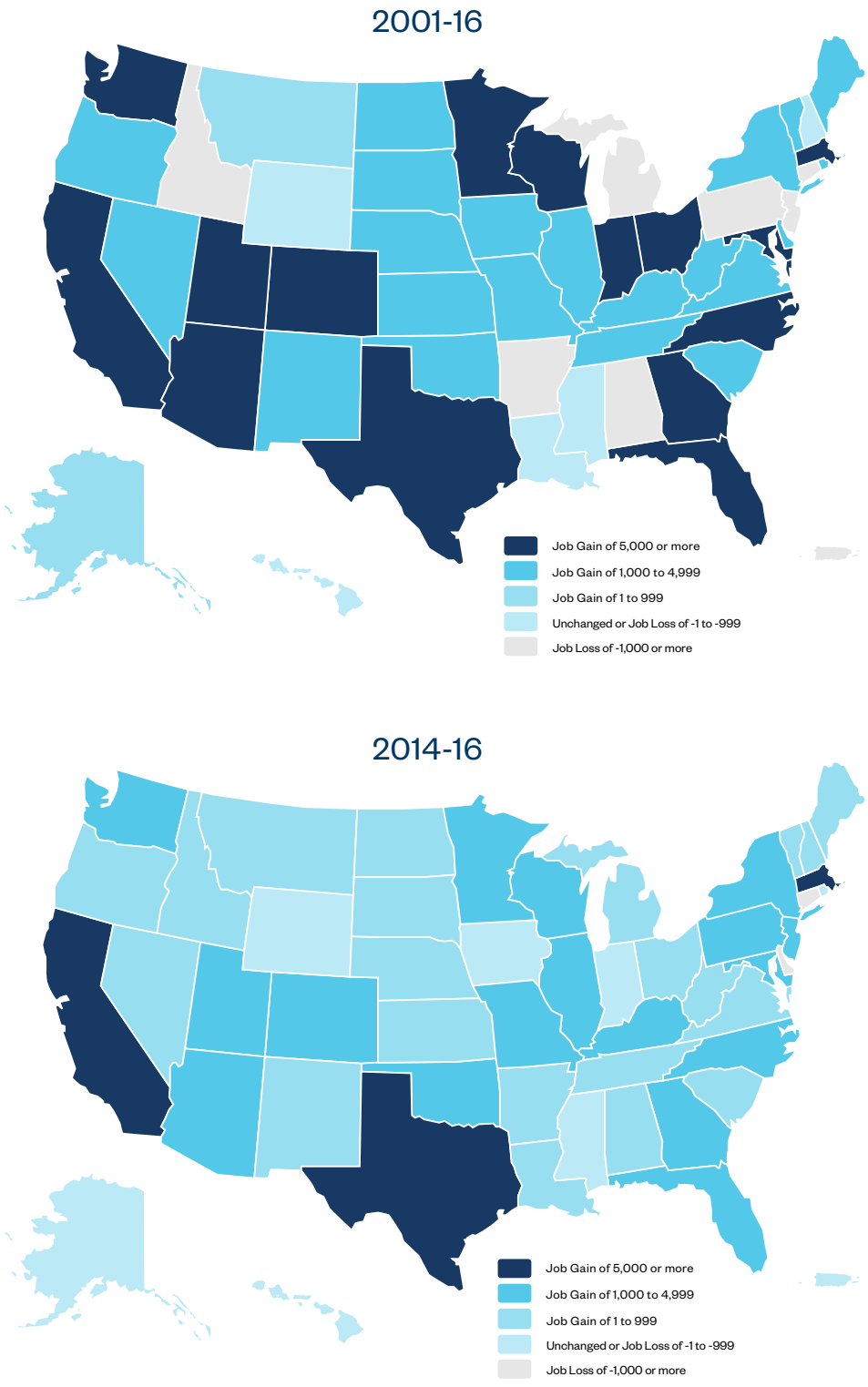
6 *State and regional location quotients (LQs) measure the degree of job concentration within the region relative to the nation. States or regions with an LQ greater than 1.0 are said to have a concentration in the subsector. When the LQ is significantly above average, 1.20 or greater, the state is said to have a "specialization" in the subsector.*

Figure 6

Change in Bioscience Employment by State, 2001-16 and 2014-16



Highlights of metropolitan area industry performance include:

- The industry is well distributed across the nation's metropolitan areas with 213 of the nation's 383 metro regions (nearly 56 percent) having a specialized employment concentration in at least one bioscience subsector.

- Twenty-six metro regions have a specialized concentration in at least three bioscience subsectors. These local areas span every region of the country, are varied in size and include (number of specializations in parentheses):
  - Boulder, CO (4)
  - Indianapolis-Carmel-Anderson, IN (4)
  - Lafayette-West Lafayette, IN (4)
  - Lincoln, NE (4)
  - Madison, WI (4)
  - Morgantown, WV (4)
  - Norwich-New London, CT (4)
  - Raleigh, NC (4)
  - Ames, IA (3)
  - Auburn-Opelika, AL (3)
  - Bloomington, IN (3)
  - Boston-Cambridge-Newton, MA-NH (3)
  - Durham-Chapel Hill, NC (3)
  - Greensboro-High Point, NC (3)
  - Iowa City, IA (3)
  - Kalamazoo-Portage, MI (3)
  - Lebanon, PA (3)
  - Logan, UT-ID (3)
  - Memphis, TN-MS-AR (3)
  - Salt Lake City, UT (3)
  - San Diego-Carlsbad, CA (3)
  - San Francisco-Oakland-Hayward, CA (3)
  - Santa Cruz-Watsonville, CA (3)
  - Syracuse, NY (3)
  - Trenton, NJ (3)
  - Worcester, MA-CT (3)

Table 5 summarizes and highlights state employment specializations and those states that grew across each major industry subsector during the 2014 to 2016 period. More on leading states and individual state performance, from both an industrial and innovation ecosystem perspective, is provided in the later sections to this report.

Table 5

State Specializations and Job Growth by Bioscience Subsector, 2016

State	Agricultural Feedstock & Industrial Biosciences		Drugs & Pharmaceuticals		Medical Devices & Equipment		Research, Testing & Medical Laboratories		Bioscience-Related Distribution	
	Specialization, 2016	Growth, 2014-16	Specialization, 2016	Growth, 2014-16	Specialization, 2016	Growth, 2014-16	Specialization, 2016	Growth, 2014-16	Specialization, 2016	Growth, 2014-16
AL	●			●				●		
AK						●				
AZ				●		●		●		●
AR	●	●		●		●		●		
CA		●	●	●	●	●	●	●		●
CO		●		●	●	●		●	●	●
CT		●			●			●		●
DE		●			●	●	●			
DC						●				
FL				●				●	●	●
GA				●		●		●		●
HI						●		●		
ID	●			●		●		●		
IL	●	●	●	●		●		●	●	●
IN	●		●	●	●	●		●		
IA	●	●		●				●	●	
KS	●			●		●	●	●		●
KY		●		●		●		●	●	●
LA	●					●		●		●
ME		●	●	●						
MD			●	●		●	●	●		●
MA		●	●	●	●	●	●	●		●
MI		●						●		●
MN	●	●		●	●	●		●	●	●
MS	●			●				●		●
MO	●	●		●		●		●		●
MT		●		●		●		●		
NE	●	●			●	●		●	●	●
NV		●		●				●		●

Table 5 Continued

State Specializations and Job Growth by Bioscience Subsector, 2016

State	Agricultural Feedstock & Industrial Biosciences		Drugs & Pharmaceuticals		Medical Devices & Equipment		Research, Testing & Medical Laboratories		Bioscience-Related Distribution	
	Specialization, 2016	Growth, 2014-16	Specialization, 2016	Growth, 2014-16	Specialization, 2016	Growth, 2014-16	Specialization, 2016	Growth, 2014-16	Specialization, 2016	Growth, 2014-16
NH				●	●	●		●		●
NJ		●	●		●	●	●	●	●	●
NM				●		●	●			
NY				●		●		●		
NC			●				●	●		●
ND	●			●		●			●	●
OH	●	●				●				●
OK	●	●		●		●		●		●
OR		●		●				●		●
PA		●	●	●		●	●	●		
PR			●	●	●	●	●		●	
RI		●	●							
SC				●						●
SD	●	●			●			●	●	●
TN				●		●		●	●	
TX				●		●		●		●
UT			●	●	●	●	●	●		●
VT		●		●	●	●		●		
VA						●				●
WA		●		●		●	●	●		●
WV	●	●	●			●				●
WI		●		●	●	●		●		●
WY	●			●		●				

Note: Solid dots represent either a specialization where state location quotient >=1.20 or employment growth > 0%.

Source: TEConomy Partners analysis of U.S. Bureau of Labor Statistics, QCEW data; enhanced file from IMPLAN.

THE INNOVATION ECOSYSTEM FOR THE U.S. BIOSCIENCE INDUSTRY

The industry-focused outcomes examined in the previous section largely describe a thriving national bioscience sector that is growing high-quality jobs. Look deeper, however, and much of the success of the industry, both past and present, is built upon a high-functioning national ecosystem that supports both basic and applied research and development with the appropriate resources, protects intellectual property, and allocates capital to promising new, emerging and existing businesses. Each of these elements, combined with the appropriate access to and pipeline for talent at all skill levels, combine to determine hard-earned economic outcomes and benefits, as well as the products and services that improve lives. This ecosystem and industry success cannot be taken for granted, particularly in a high-stakes, globally competitive environment.

This section examines the national trends for four key elements of the industry's unique innovation ecosystem.

Bioscience Innovation Ecosystem, Featured Measures

- NIH Funding
- Academic Bioscience R&D Expenditures
- Bioscience Patents
- Bioscience Venture Capital Investments

R&D Funding and Expenditures: Ecosystem Bolstered by Increasing NIH Budgets

Federal funding for bioscience-related research is a critical element to advance a science-driven industry. Several agencies fund life sciences research at U.S. colleges and universities, with the National Institutes of Health (NIH) recognized as the "gold standard" for the largest component of bioscience research—biomedical. NIH also funds research at hospitals and other biomedical research institutions. According to NIH, it currently invests $37 billion in annual research, with a majority of that funding awarded to the external

research community and a smaller fraction invested in internal research. According to NIH:

> *"More than 80% of the NIH's funding is awarded through almost 50,000 competitive grants to more than 300,000 researchers at more than 2,500 universities, medical schools and other research institutions in every state and around the world."* [7]

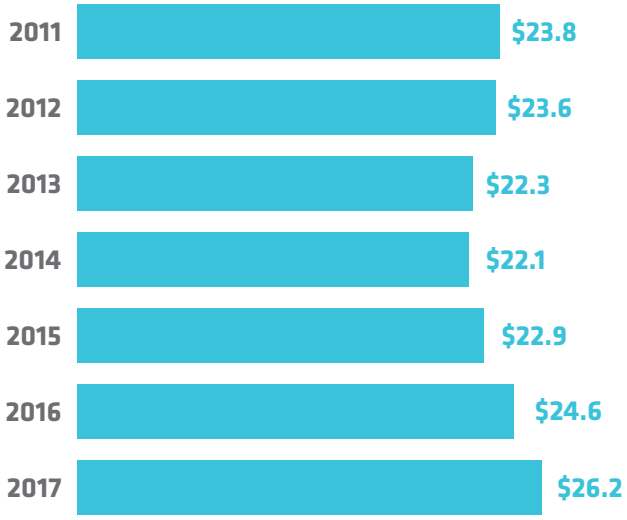
While the role of federal research is well understood as vital to the biosciences, a new study finds that NIH-funding contributed to published scientific research associated with every new medicine approved by the Food and Drug Administration (FDA) over the 2010 through 2016 period.[8] The study, conducted by a team at Bentley University, focused on more than $100 billion in grant-funded research invested by the NIH that ultimately helped lead to the 210 new medicines approved during the 6-year period. The authors find that more than 90 percent of this activity was in basic research related to biological targets rather than specific therapeutics, thus emphasizing the importance not only of applied but also complementary basic research for drug development.

For several years, concerns have been raised regarding declining and/or flat NIH research budgets and the subsequent effects on academic and other research. Fortunately for the bioscience community, NIH funding is back on the rise. After peaking in 2003, and excluding one-time federal ARRA stimulus funding in 2009 and 2010, the overall NIH budget has seen year-to-year declines or been flat with no substantial increase until 2016. Budget increases have been sustained each of the last three years, with FY 2016-18 R&D budgets increasing an average of 4.8 percent annually, though still well below the double-digit budget increases seen in the late 1990s and early 2000s.[9]

The recent NIH budget increases have translated into a steadily growing funding base for extramural research awards (Figure 7). Since 2014, awards have increased by nearly $4.1 billion or 18.5 percent.

Figure 7

National Institutes of Health Awards, FY 2011-17 ($ in billions)



Source: TEConomy Partners analysis of National Institutes of Health RePORT data.

NIH research funding directly impacts trends in bioscience-related academic research, as health sciences represents a majority (53 percent) of these expenditure totals. The 2016 TEConomy/BIO report had found a slow-growth situation for academic bioscience R&D expenditures, affected in part by the trends in NIH funding, but bolstered by increases in

7 *See: https://www.nih.gov/about-nih/what-we-do/budget#note*

8 *Cleary, et al, "Contribution of NIH funding to new drug approvals 2010–2016," Proceedings of the National Academy of Sciences, February 12, 2018.*

9 *AAAS R&D report series, based on OMB data, agency budget documents and information from agency budget offices. FY 2018 figures are omnibus-enacted amounts. Accessed from AAAS at: https://www.aaas.org/page/historical-trends-federal-rd*

other funding sources, namely from the institutions themselves, industry and state and local governments. Following a 1.5 percent decline in 2015, academic R&D expenditures in the biosciences increased a healthy 5.5 percent to $42 billion in 2016 (Figure 8).

Figure 8
University Bioscience R&D Expenditures, FY 2014-16 ($ in billions)

Source: TEConomy Partners analysis of National Science Foundation (NSF) Higher Education Research and Development (HERD) Survey.

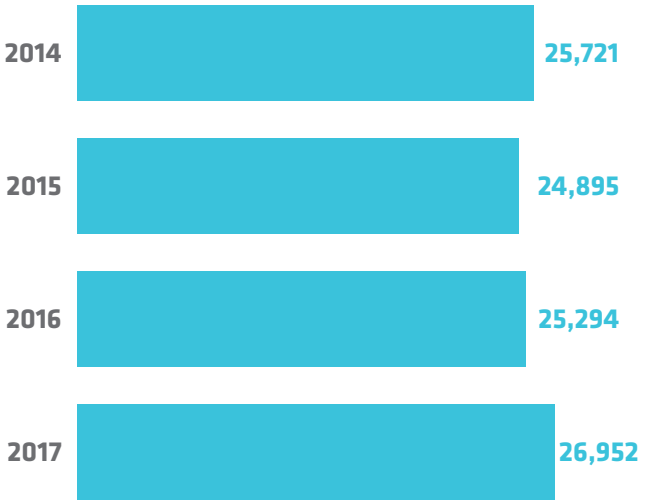
Patent Activity Reflects Expanding Innovation

Bioscience-related innovation is uniquely challenging. The length of time and levels of resources required to successfully navigate the research and development and regulatory requirements of a commercial therapeutic, medical device, or a biobased product is daunting. Tufts University, for example, has estimated the cost to develop an FDA-approved new prescription drug at more than $2.5 billion, and finds that drug development often takes more than a decade.[10] Robust and enforced legal protections of intellectual property, in the form of patents, are necessary to encourage and incent these types of investments both in the U.S. and globally.

The U.S. has increased patent totals in bioscience-related technology classes by nearly 5 percent since 2014 (Figure 9), or 1.6 percent per year, on average. While 2015 and 2016 had lower numbers of total patents awarded to a U.S. inventor, 2017 saw the total rise to nearly 27,000, a new high.

The breadth of innovation activity within the biosciences is reflected in the patent class groupings in Figure 10. Over the recent 4-year period, one of every two new inventions was classified within medical and surgical devices, which spans a wide range of products and markets from orthopedic, dental, ultrasound and veterinary instruments and equipment to sterilizing applications and operating room equipment. Drug and pharmaceutical patents represent not only a large innovation area but also one of the fastest-growing—from 2014 to 2017 this group had an average annual growth rate in patent awards of 5.6 percent. Genetics innovations, within the broader microbiology and genetics grouping, have increased by an average of 6.5 percent annually.

Figure 9
Bioscience-related U.S. Patents, 2014-17

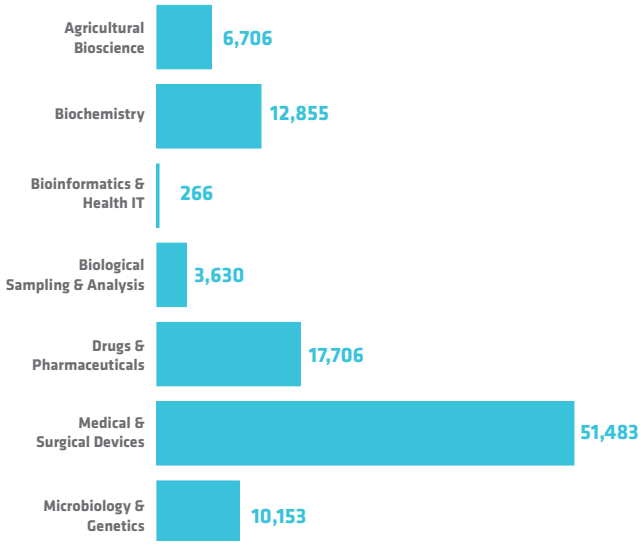


Source: TEConomy Partners analysis of U.S. Patent & Trademark Office data from Clarivate Analytics' Derwent Innovation patent analysis database.

10 *DiMasi, Grabowski and Hansen, "Innovation in the pharmaceutical industry: New estimates of R&D costs," Journal of Health Economics, May 2016.*

Figure 10

Bioscience-related U.S. Patents by Segment, Cumulative 2014-17



Source: TEConomy Partners analysis of U.S. Patent & Trademark Office data from Clarivate Analytics' Derwent Innovation patent analysis database.

Venture Capital Investments in the Biosciences Reach New Highs

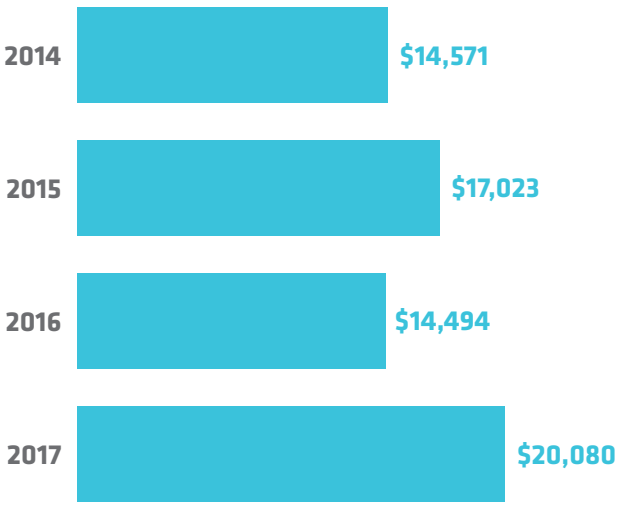
Access to capital is especially vital for R&D-intensive bioscience companies facing long time horizons to guide innovations through to commercial outcomes and steady revenues. In particular, seed-stage and early-stage companies require funding, often in multiple tranches or rounds to sustain their product development as well as to conduct the rigorous pre-clinical and clinical testing required to meet industry regulations.

More than $66 billion in venture capital was invested in bioscience companies in the 2014 through 2017 period (Figure 11). It is common to see year-to-year variability in the levels of investments, but there has been an upward trend in industry investing with new highs reached in the biosciences in 2015 (at $17.0 billion) and then again in 2017 when nearly $20.1 billion was invested. After reaching the $10 billion threshold back in 2007 at the peak of the prior expansion, the biosciences did not again surpass this milestone until 2013. It then took just 4 years to reach $20 billion, a new high for the industry.

The recent increases in dollar volumes directed toward bioscience companies coincide, however, with greater overall VC investments in U.S. companies. Since 2001 the biosciences have averaged 25 percent of total venture investments, but in the recent 4-year period the industry's share has been lower at 21 percent, reflecting greater resources directed toward IT companies in particular. Likewise, biosciences' share of all VC deal activity (number of deals) has averaged 19 percent since 2001, but in recent years this average declined to 15 percent.

Figure 11

Bioscience-related Venture Capital Investments, 2014-17 ($ in millions)



Source: TEConomy Partners analysis of data from PitchBook Data, Inc.

Industry investments broken out by company stage show that a majority of the $66.2 billion invested (55 percent) has gone to later-stage bioscience companies during the recent 4-year period. This is essentially the same share that has been allocated to the later stage

bioscience investments, on average, since 2001 (56.5 percent) and this share had been rising—peaking in 2014 with 65 percent of investments in the later stage companies. In 2016 and 2017, however, the share of funding to earlier stage companies increased and in 2017 the earlier-stage funding instead accounted for a majority, 54 percent, the first observation of a majority since 2001. Though one or two observations does not necessarily indicate a trend, it will be important to track this improved situation for earlier-stage companies' access to risk capital.

About one-third of industry VC funding was invested in biotechnology companies over the last 4 years (Figure 12). Companies engaged in drug discovery and delivery received $13.4 billion or 20 percent of the industry's total. Health technologies, which includes companies with IT and other electronic applications such as enterprise and electronic medical records systems, reached $8.1 billion during this period.

Investments in ag biotech are included within agricultural chemicals and biofuels categories, but areas such as animal health and animal biotechnology are captured across other groupings including biotechnology, pharmaceuticals and the various medical device categories. A separate source for investments in a wide range of "AgriFood" technologies, AgFunder, has seen a rebound and rise in private funding for new firms through the first half of 2017 after a dip in 2016.[11] AgFunder tracks a broad range of firms deploying technologies on farms, in the agricultural supply chain, among retailers and those used by consumers.

Table 6
U.S. Bioscience Venture Capital Investments by Stage, 2014-2017

Stage	Number of Deals	Number of Companies	Total VC Investments ($ Millions)	Average Per Deal ($ Millions)	Average Investment Per Company ($ Millions)
Pre-seed	1,756	1,329	$136	$0.08	$0.10
Angel	1,586	1,252	$3,182	$2.01	$2.54
Seed	807	688	$1,272	$1.58	$1.85
Early Stage	1,967	1,489	$25,035	$12.73	$16.81
Later Stage	1,816	1,169	$36,544	$20.12	$31.26
Total	**7,932**	**4,762**	**$66,169**	**$8.34**	**$13.90**

Note: Company totals by stage will not sum to the total as individual companies progress in their stage and often receive multiple investments during a multi-year time frame. Pre-Seed stage includes accelerator, incubator and even crowdfunding-based sources.

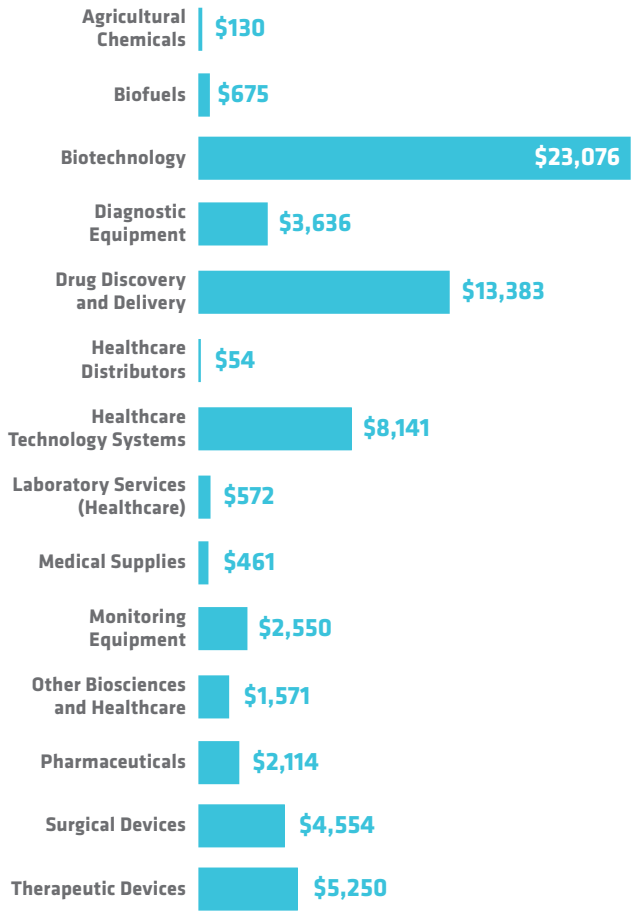
Source: TEConomy Partners analysis of PitchBook Data, Inc.

11 AgFunder AgriFood Tech Investing Report, Mid-year Review 2017.

The performance of and situation for the bioscience innovation ecosystem is quite positive in this latest assessment of selected elements. In recent years, the ecosystem has seen rising NIH budgets and an increase in academic R&D, growth in patent activity and record levels of private investments in the industry are helping to contribute to advancing innovation and industry growth. The U.S., however, cannot be complacent. The international competition for the biosciences is fierce. This ecosystem can be fragile, affected by economic cycles, and key components such as federal funding are subject to political shifts and budget constraints.

Figure 12

Bioscience-related Venture Capital Investments by Segment, 2014-17 ($ in millions)



Source: TEConomy Partners analysis of data from PitchBook Data, Inc.

STATE AND METROPOLITAN AREA PERFORMANCE

This section provides an in-depth examination of employment trends for states among each of the five major bioscience subsectors. Data were tabulated for each state, the District of Columbia and Puerto Rico, and for every U.S. Metropolitan Statistical Area (MSA) to determine the size and relative job concentration within each subsector. In addition, employment growth and loss were calculated to highlight recent trends.

The key metrics used in this section include:

- **Employment size** measures the absolute level of jobs within each region.
    - To allow for meaningful comparisons, each region's share of total U.S. subsector employment was analyzed. States with 5 percent or more of national employment are designated "large"; states with more than 3 percent but less than 5 percent are referred to as "sizable."
    - For metropolitan regions, a table is included for each subsector presenting the top 25 metropolitan regions in employment.
- **Employment concentration** is a useful way in which to gauge the relative size of a region's subsectors relative to the national average. While employment size reveals the largest geographic components, employment concentration can reveal the relative importance of the subsectors to a regional or state economy.
    - State and regional location quotients (LQs) measure the degree of job concentration within the region relative to the nation. States or regions with an LQ greater than 1.0 are said to have a concentration in the subsector. When the LQ is significantly above average, 1.20 or greater, the state is said to have a "specialization" in the subsector.
    - For metropolitan regions, a table is provided presenting the top 15 metropolitan areas according to LQs, based on the size of the region (either small, medium or large).

- The level of **employment growth or loss** over the 2014 to 2016 period provides a way to measure the performance of a state's bioscience sector. In this analysis, job growth or loss was measured by absolute employment gains or losses, as percentage changes may overstate trends in those states with a smaller subsector employment base.

Agricultural Feedstock & Industrial Biosciences

The agricultural feedstock and industrial biosciences subsector applies life sciences knowledge, biochemistry and biotechnologies to the processing and production of agricultural goods as well as organic and agricultural chemicals. The subsector also includes activities around the production of biofuels and feedstocks for biobased polymers.[12]

Examples of Products

- Fertilizers, pesticides, herbicides, fungicides and agricultural microbials
- Corn and soybean oil
- Ethanol and biodiesel fuels
- Organic chemicals made from renewable resources or through biological processes
- Polymers, plastics and textiles synthesized from plant-based feedstock or through biological processes
- Biocatalysts
- Biobased ingredients for cosmetics, personal care products, flavors and fragrances

Examples of Companies

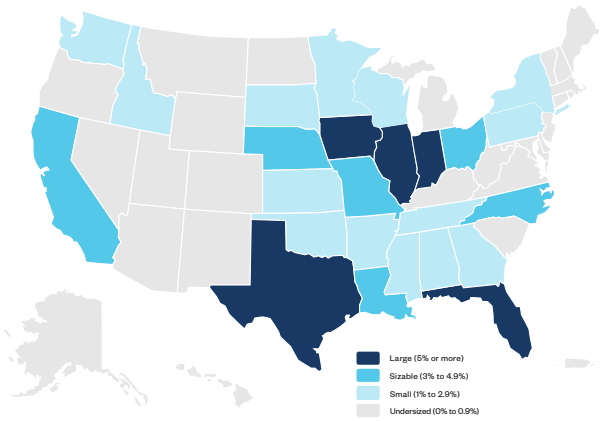
- Amyris
- BASF Enzymes
- Bayer CropScience
- DSM
- Corteva Agriscience
- DuPont Industrial Biosciences
- Evolva
- Genus
- Intrexon
- Monsanto
- Novozymes
- Poet
- Scotts Miracle-Gro
- Simplot Plant Sciences
- Syngenta

States that are Both Large and Specialized*

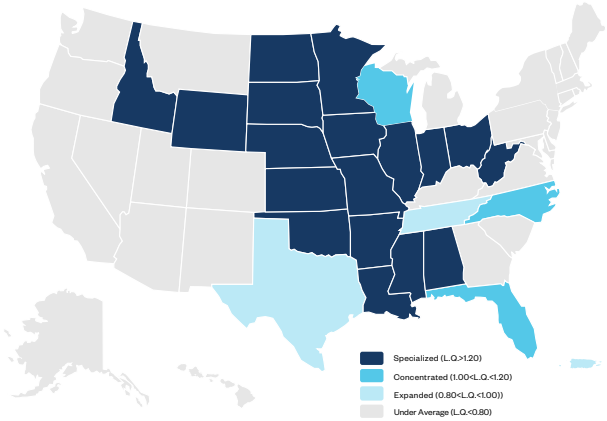
- Illinois
- Iowa
- Indiana

**States are listed in descending order by subsector employment levels.*

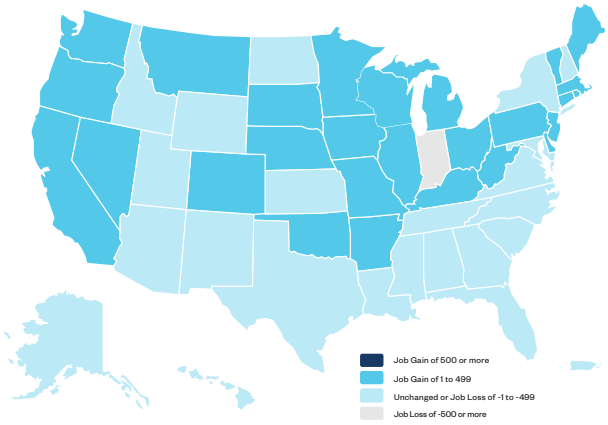
State Share of Total U.S. Employment
2016



Employment Concentration Relative to the U.S.
2016



Employment Gains and Losses
2014-2016



12 For further information and context regarding this subsector, please also see the discussion regarding Industrial Biotechnology and the Biobased Economy in the previous section of this report.

Agricultural Feedstock & Industrial Biosciences

State Leaders & Highlights

Employment Size: Employment is relatively concentrated in the top 11 states, which account for 68 percent of employment in this subsector. Those 11 states are:

- **Large States**: Illinois, Iowa, Texas, Florida, Indiana
- **Sizable States**: California, Ohio, Nebraska, Louisiana, Missouri, North Carolina

Employment Concentration: Eighteen states have a specialized concentration of jobs in the agricultural feedstock and industrial biosciences subsector, more than for any other subsector. These concentrations are in the Midwest and South.

- **Specialized States**: Iowa, Nebraska, South Dakota, Illinois, Louisiana, Idaho, Indiana, Wyoming, North Dakota, West Virginia, Missouri, Kansas, Alabama, Mississippi, Oklahoma, Arkansas, Minnesota, Ohio
- **Concentrated States**: North Carolina, Florida, Wisconsin

Employment Growth: Over the 2014 to 2016 period, 27 states experienced some increase in subsector employment, with Ohio, West Virginia and Wisconsin experiencing the largest gains.

Large and Specialized States: Three states have both high employment and a specialized concentration of jobs in agricultural feedstock and industrial biosciences (Table 7).

Table 8

Metropolitan Statistical Areas with the Largest Employment Levels in Agricultural Feedstock and Industrial Biosciences, 2016

Metropolitan Statistical Area	2016 Employment
Decatur, IL	5,114
Houston-The Woodlands-Sugar Land, TX	2,136
Lakeland-Winter Haven, FL	1,642
Chicago-Naperville-Elgin, IL-IN-WI	1,399
Baton Rouge, LA	1,126
Cedar Rapids, IA	1,125
Tampa-St. Petersburg-Clearwater, FL	1,092
Indianapolis-Carmel-Anderson, IN	1,056
New Orleans-Metairie, LA	1,003
Memphis, TN-MS-AR	879
Sioux City, IA-NE-SD	868
Omaha-Council Bluffs, NE-IA	704
St. Louis, MO-IL	697
Kansas City, MO-KS	686
Peoria, IL	623
New York-Newark-Jersey City, NY-NJ-PA	621
Dallas-Fort Worth-Arlington, TX	607
Charleston, WV	586
Lafayette-West Lafayette, IN	559
Columbus, OH	548
Des Moines-West Des Moines, IA	536
Madison, WI	498
Phoenix-Mesa-Scottsdale, AZ	460
Los Angeles-Long Beach-Anaheim, CA	441
Orlando-Kissimmee-Sanford, FL	426

Table 7

States with Large and Specialized Employment in Agricultural Feedstock and Industrial Biosciences, 2016

State	Establishments, 2016	Employment, 2016	Location Quotient, 2016	Share of U.S. Employment
Illinois	82	8,529	2.97	12.5%
Iowa	125	7,952	10.85	11.7%
Indiana	50	3,599	2.46	5.3%

Table 9

Metropolitan Statistical Areas with the Highest Location Quotients in Agricultural Feedstock and Industrial Biosciences, by size of MSA, 2016

Metropolitan Statistical Area	Location Quotient	2016 Employment
Large MSAs (Total Private Employment Greater than 250,000		
Baton Rouge, LA	6.23	1,126
New Orleans-Metairie, LA	3.71	1,003
Des Moines-West Des Moines, IA	3.06	536
Omaha-Council Bluffs, NE-IA	3.00	704
Madison, WI	2.89	498
Memphis, TN-MS-AR	2.88	879
Fresno, CA	2.19	387
Indianapolis-Carmel-Anderson, IN	2.12	1,056
Dayton, OH	1.86	328
Tampa-St. Petersburg-Clearwater, FL	1.71	1,092
Knoxville, TN	1.67	306
Toledo, OH	1.56	230
Houston-The Woodlands-Sugar Land, TX	1.48	2,136
Kansas City, MO-KS	1.36	686
Wichita, KS	1.18	170
Medium MSAs (Total Private Employment Between 75,000 and 250,000)		
Sioux City, IA-NE-SD	19.81	868
Cedar Rapids, IA	15.98	1,125
Lakeland-Winter Haven, FL	15.51	1,642
Charleston, WV	11.85	586
Peoria, IL	7.20	623
Lubbock, TX	5.49	350
Fayetteville, NC	4.13	211
Mobile, AL	3.85	324
Evansville, IN-KY	3.52	275
Stockton-Lodi, CA	3.00	341
Jackson, MS	2.84	336
Beaumont-Port Arthur, TX	2.72	212
Greeley, CO	2.71	130
Brownsville-Harlingen, TX	2.34	146
Yakima, WA	2.29	122
Small MSAs (Total Private Employment Less than 75,000)		
Decatur, IL	200.85	5,114
Danville, IL	15.76	197
Mankato-North Mankato, MN	15.32	407
St. Joseph, MO-KS	15.27	412
Decatur, AL	14.98	377
Lafayette-West Lafayette, IN	13.68	559
Enid, OK	12.83	169
Grand Island, NE	10.79	220
Hanford-Corcoran, CA	8.41	152
Kankakee, IL	7.98	168
Muskegon, MI	5.80	185
Pocatello, ID	5.77	86
Florence-Muscle Shoals, AL	5.65	144
Lima, OH	5.30	136
Sierra Vista-Douglas, AZ	4.93	63

Drugs & Pharmaceuticals

The drugs and pharmaceuticals subsector produces commercially available medicinal and diagnostic substances. The subsector is generally characterized by large multinational firms heavily engaged in R&D and manufacturing activities to bring drugs to market.

Examples of Products

- Biopharmaceuticals
- Vaccines
- Targeted disease therapeutics
- Tissue and cell culture media
- Dermatological/topical treatments
- Diagnostic substances
- Animal vaccines and therapeutics

Examples of Companies

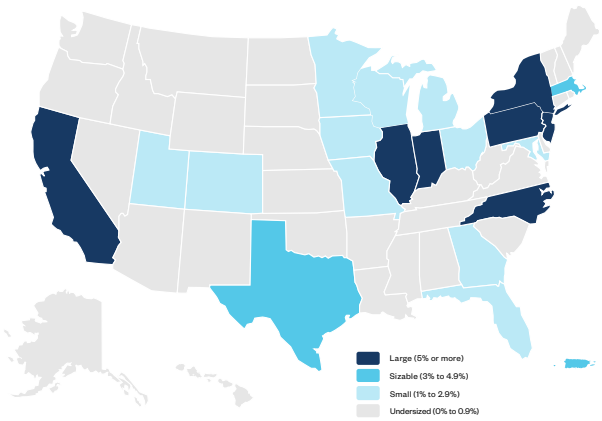
- Acorda Therapeutics
- Alkermes
- Alnylam Pharmaceuticals
- Amgen
- Bayer
- Biogen
- Eli Lilly and Company
- GlaxoSmithKline
- Novo Nordisk
- Pfizer
- Roche Group-Genentech
- Sangamo Therapeutics
- Vertex Pharmaceuticals

States that are Both Large and Specialized*

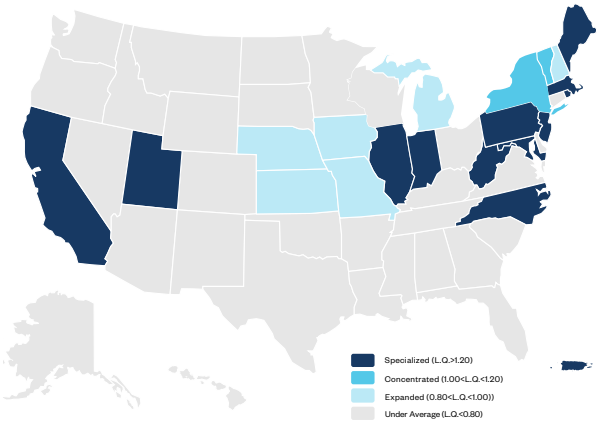
- California
- New Jersey
- North Carolina
- Illinois
- Pennsylvania
- Indiana

**States are listed in descending order by subsector employment levels.*

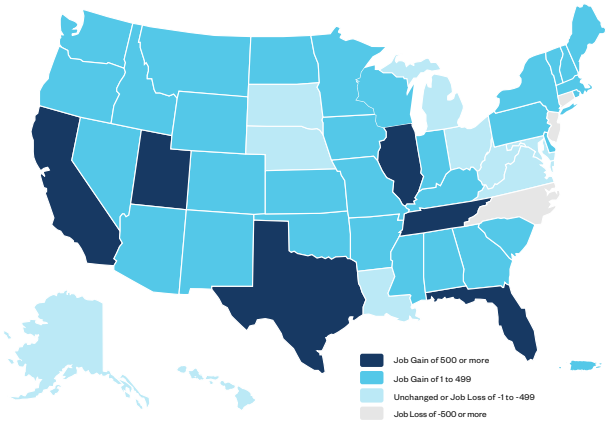
State Share of Total U.S. Employment
2016



Employment Concentration Relative to the U.S.
2016



Employment Gains and Losses
2014-2016



Drugs & Pharmaceuticals

State Leaders & Highlights

Employment Size: Drugs and pharmaceuticals manufacturing has a relatively high concentration among the leading states. The six largest employer states in this subsector account for half of U.S. employment.

- **Large States**: California, New Jersey, North Carolina, Illinois, New York, Pennsylvania, Indiana
- **Sizable States**: Puerto Rico, Texas, Massachusetts

Employment Concentration: Twelve states and Puerto Rico have a specialized concentration of jobs in the drugs and pharmaceuticals subsector.

- **Specialized States**: Puerto Rico, Indiana, New Jersey, North Carolina, Utah, West Virginia, Illinois, Maine, California, Pennsylvania, Maryland, Massachusetts, Rhode Island
- **Concentrated States**: New York, Vermont

Employment Growth: Over the 2014 to 2016 period, 36 states and Puerto Rico experienced some increase in subsector employment. Of those states, California, Illinois, Texas, Utah, Florida and Tennessee experienced substantial job increases.

Large and Specialized States: Six states have both high employment and a specialized concentration of jobs in drugs and pharmaceuticals (Table 10).

Table 11

Metropolitan Statistical Areas with the Largest Employment Levels in Drugs and Pharmaceuticals, 2016

Metropolitan Statistical Area	2016 Employment
New York-Newark-Jersey City, NY-NJ-PA	31,793
Chicago-Naperville-Elgin, IL-IN-WI	18,317
San Francisco-Oakland-Hayward, CA	16,153
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	14,576
Indianapolis-Carmel-Anderson, IN	13,008
Los Angeles-Long Beach-Anaheim, CA	12,243
Boston-Cambridge-Newton, MA-NH	9,439
San Diego-Carlsbad, CA	7,018
Durham-Chapel Hill, NC	5,922
Oxnard-Thousand Oaks-Ventura, CA	5,734
Washington-Arlington-Alexandria, DC-VA-MD-WV	4,841
Dallas-Fort Worth-Arlington, TX	4,273
St. Louis, MO-IL	3,563
Vallejo-Fairfield, CA	3,509
Raleigh, NC	3,270
Rocky Mount, NC	3,041
Minneapolis-St. Paul-Bloomington, MN-WI	2,923
Miami-Fort Lauderdale-West Palm Beach, FL	2,696
Kalamazoo-Portage, MI	2,649
Houston-The Woodlands-Sugar Land, TX	2,561
Salt Lake City, UT	2,510
Morgantown, WV	2,463
San Jose-Sunnyvale-Santa Clara, CA	2,408
East Stroudsburg, PA	2,304
Trenton, NJ	2,213

Table 10

States with Large and Specialized Employment in Drugs and Pharmaceuticals, 2016

State	Establishments, 2016	Employment, 2016	Location Quotient, 2016	Share of U.S. Employment
California	531	50,456	1.44	16.9%
New Jersey	268	22,846	2.75	7.6%
North Carolina	125	20,656	2.34	6.9%
Illinois	185	20,102	1.59	6.7%
Pennsylvania	121	17,885	1.43	6.0%
Indiana	47	17,862	2.78	6.0%

Table 12

Metropolitan Statistical Areas with the Highest Location Quotients in Drugs and Pharmaceuticals, by size of MSA, 2016

Metropolitan Statistical Area	Location Quotient	2016 Employment
Large MSAs (Total Private Employment Greater than 250,000		
Oxnard-Thousand Oaks-Ventura, CA	8.61	5,734
Indianapolis-Carmel-Anderson, IN	6.19	13,008
San Francisco-Oakland-Hayward, CA	3.30	16,153
Madison, WI	2.88	2,098
Raleigh, NC	2.69	3,270
Albany-Schenectady-Troy, NY	2.63	2,182
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2.49	14,576
San Diego-Carlsbad, CA	2.46	7,018
Worcester, MA-CT	2.41	1,879
Chicago-Naperville-Elgin, IL-IN-WI	1.91	18,317
Greenville-Anderson-Mauldin, SC	1.88	1,505
Salt Lake City, UT	1.81	2,510
Buffalo-Cheektowaga-Niagara Falls, NY	1.74	1,904
Boston-Cambridge-Newton, MA-NH	1.69	9,439
New York-Newark-Jersey City, NY-NJ-PA	1.68	31,793
Medium MSAs (Total Private Employment Between 75,000 and 250,000)		
Vallejo-Fairfield, CA	13.05	3,509
Durham-Chapel Hill, NC	10.48	5,922
Kalamazoo-Portage, MI	8.92	2,649
Trenton, NJ	5.10	2,213
Santa Cruz-Watsonville, CA	3.75	778
Waco, TX	3.63	843
Provo-Orem, UT	3.26	1,502
Ogden-Clearfield, UT	3.06	1,423
Lincoln, NE	3.01	1,029
Portland-South Portland, ME	2.83	1,572
Boulder, CO	2.83	1,003
Norwich-New London, CT	2.71	610
Burlington-South Burlington, VT	2.52	614
Huntsville, AL	2.47	1,008
Fort Collins, CO	2.42	703
Small MSAs (Total Private Employment Less than 75,000)		
Rocky Mount, NC	26.72	3,041
East Stroudsburg, PA	20.84	2,304
Morgantown, WV	20.19	2,463
Kankakee, IL	15.02	1,339
Greenville, NC	12.73	1,603
Bloomington, IN	10.66	1,285
St. Joseph, MO-KS	10.07	1,149
Logan, UT-ID	8.84	957
Athens-Clarke County, GA	7.31	1,111
Lebanon, PA	5.89	593
Iowa City, IA	3.93	581
Harrisonburg, VA	3.86	497
Lafayette-West Lafayette, IN	3.66	632
Terre Haute, IN	3.53	476
Cleveland, TN	3.42	322

Medical Devices & Equipment

Firms in the medical device and equipment subsector produce a variety of biomedical instruments and other healthcare products and supplies for diagnostics, surgery, patient care and laboratories. The subsector is continually advancing the application of electronics and information technologies to improve and automate testing and patient care capabilities.

Examples of Products

- Bioimaging equipment
- Surgical supplies and instruments
- Orthopedic/prosthetic implants and devices
- Genomic sequencing equipment
- Automated external defibrillators (AEDs)
- Vascular stents and other implantable devices
- Dental instruments and orthodontics

Examples of Companies

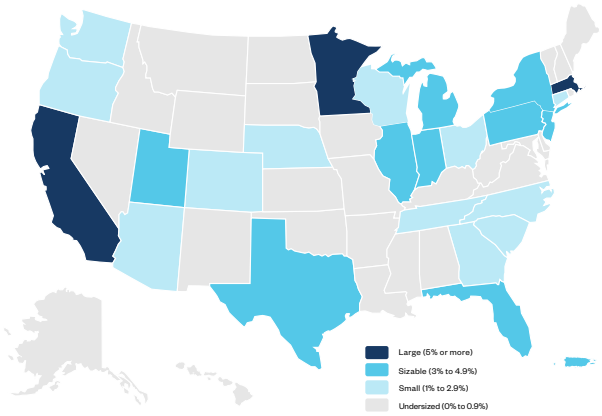
- 3M Health Care
- Becton, Dickinson and Co.
- Boston Scientific Corp.
- Cook Medical
- DuPuy Synthes
- GE Healthcare
- Medtronic
- Philips Healthcare
- Regenesis Biomedical
- Siemens Medical Solutions
- Stryker
- Zimmer

States that are Both Large and Specialized*

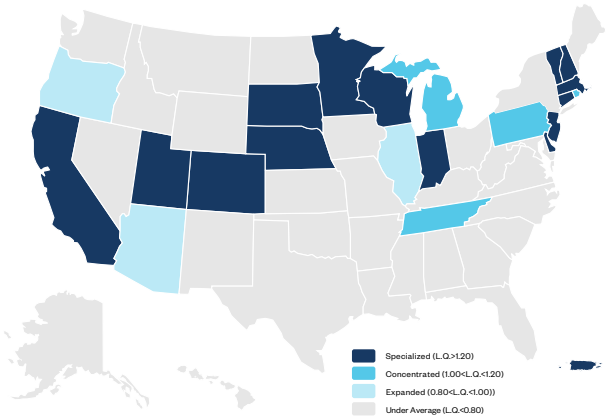
- California
- Minnesota
- Massachusetts

**States are listed in descending order by subsector employment levels.*

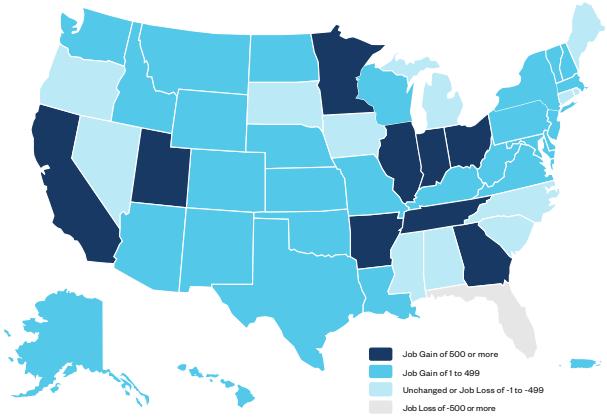
State Share of Total U.S. Employment
2016



Employment Concentration Relative to the U.S.
2016



Employment Gains and Losses
2014-2016



Medical Devices & Equipment

State Leaders & Highlights

Employment Size: The medical device subsector has a well-distributed geographic footprint, with large or sizable states in every region. The top ten employing states continue to account for almost 60 percent of employment in this subsector.

- **Large States**: California, Minnesota, Massachusetts
- **Sizable States**: Indiana, Florida, Pennsylvania, Puerto Rico, Illinois, New Jersey, New York, Utah, Michigan, Texas

Employment Concentration: Fourteen states and Puerto Rico have a specialized concentration of jobs in the medical device and equipment subsector.

- **Specialized States**: Puerto Rico, Minnesota, Utah, Massachusetts, Indiana, Delaware, Connecticut, Nebraska, South Dakota, Colorado, California, New Hampshire, Wisconsin, Vermont, New Jersey
- **Concentrated States**: Tennessee, Pennsylvania, Rhode Island, Michigan

Employment Growth: Over the 2014 to 2016 period, 37 states, Puerto Rico and D.C. experienced some increase in subsector employment with 9 states having substantial increases led by California, Minnesota, Utah, Illinois and Arkansas.

Large and Specialized States: Three states have both high employment and a specialized concentration of jobs in medical devices and equipment (Table 13).

Table 14

Metropolitan Statistical Areas with the Largest Employment Levels in Medical Devices and Equipment, 2016

Metropolitan Statistical Area	2016 Employment
Los Angeles-Long Beach-Anaheim, CA	27,935
Minneapolis-St. Paul-Bloomington, MN-WI	26,440
Boston-Cambridge-Newton, MA-NH	16,567
New York-Newark-Jersey City, NY-NJ-PA	15,954
Chicago-Naperville-Elgin, IL-IN-WI	12,391
Salt Lake City, UT	8,948
San Francisco-Oakland-Hayward, CA	8,841
San Diego-Carlsbad, CA	8,668
San Jose-Sunnyvale-Santa Clara, CA	7,621
Milwaukee-Waukesha-West Allis, WI	6,199
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	6,019
Memphis, TN-MS-AR	5,876
Pittsburgh, PA	5,072
Seattle-Tacoma-Bellevue, WA	4,722
Denver-Aurora-Lakewood, CO	4,645
Miami-Fort Lauderdale-West Palm Beach, FL	4,609
Cleveland-Elyria, OH	4,530
Providence-Warwick, RI-MA	4,045
Dallas-Fort Worth-Arlington, TX	4,028
Bloomington, IN	3,934
Portland-Vancouver-Hillsboro, OR-WA	3,850
Raleigh, NC	3,417
Tampa-St. Petersburg-Clearwater, FL	3,264
Boulder, CO	3,085
New Haven-Milford, CT	3,025

Table 13

States with Large and Specialized Employment in Medical Devices and Equipment, 2016

State	Establishments, 2016	Employment, 2016	Location Quotient, 2016	Share of U.S. Employment
California	1,183	62,686	1.49	17.4%
Minnesota	343	27,555	3.80	7.7%
Massachusetts	288	21,378	2.35	6.0%

Table 15

Metropolitan Statistical Areas with the Highest Location Quotients in Medical Devices and Equipment, by size of MSA, 2016

Metropolitan Statistical Area	Location Quotient	2016 Employment
Large MSAs (Total Private Employment Greater than 250,000		
Minneapolis-St. Paul-Bloomington, MN-WI	5.45	26,440
Salt Lake City, UT	5.31	8,948
Memphis, TN-MS-AR	3.75	5,876
New Haven-Milford, CT	3.23	3,025
Milwaukee-Waukesha-West Allis, WI	2.85	6,199
San Jose-Sunnyvale-Santa Clara, CA	2.66	7,621
San Diego-Carlsbad, CA	2.50	8,668
Boston-Cambridge-Newton, MA-NH	2.45	16,567
Raleigh, NC	2.31	3,417
Providence-Warwick, RI-MA	2.28	4,045
Worcester, MA-CT	2.10	1,994
Syracuse, NY	2.04	1,475
Bridgeport-Stamford-Norwalk, CT	1.96	2,203
Rochester, NY	1.85	2,347
Madison, WI	1.85	1,638
Medium MSAs (Total Private Employment Between 75,000 and 250,000)		
Kalamazoo-Portage, MI	8.19	2,953
Boulder, CO	7.16	3,085
Gainesville, FL	5.18	1,452
Santa Rosa, CA	4.85	2,491
Ocala, FL	3.52	898
Naples-Immokalee-Marco Island, FL	3.37	1,288
Ogden-Clearfield, UT	3.36	1,902
Reading, PA	2.95	1,319
Colorado Springs, CO	2.75	1,774
Santa Maria-Santa Barbara, CA	2.58	1,230
Ann Arbor, MI	2.43	931
Saginaw, MI	2.27	502
Utica-Rome, NY	2.27	606
Huntington-Ashland, WV-KY-OH	2.26	715
Manchester-Nashua, NH	2.02	1,079
Small MSAs (Total Private Employment Less than 75,000)		
Bloomington, IN	26.85	3,934
Flagstaff, AZ	19.35	2,562
Niles-Benton Harbor, MI	12.25	1,934
Glens Falls, NY	10.42	1,349
State College, PA	7.21	963
Sumter, SC	6.77	612
Staunton-Waynesboro, VA	3.16	370
Decatur, IL	2.80	366
Sheboygan, WI	2.76	439
Dover, DE	2.66	402
Logan, UT-ID	2.58	340
Lebanon, PA	2.50	306
Auburn-Opelika, AL	2.27	284
Michigan City-La Porte, IN	2.25	226
Bellingham, WA	1.60	340

Research, Testing & Medical Laboratories

The research, testing and medical laboratories subsector includes firms performing a range of activities; from highly research-oriented companies working to develop and commercialize new industrial biotechnologies, drug discovery/delivery systems and gene and cell therapies, to more service-oriented firms engaged in medical and other life sciences testing services.

Examples of Products

- Stem cell/regenerative research
- Molecular diagnostics and testing
- Preclinical drug development
- Drug delivery systems
- DNA synthesis
- Research/laboratory support services

Examples of Companies

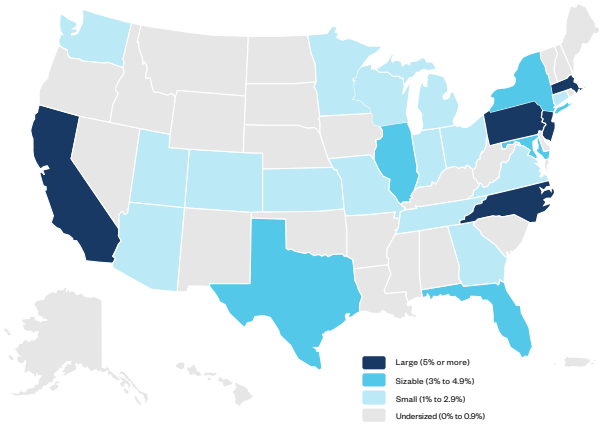
- Albany Molecular Research
- Algenol Biotech
- Bayer CropScience
- Charles River Laboratories
- Complete Genomics
- Corteva Agriscience
- Covance
- IQVIA
- Laboratory Corp. of America
- Monsanto
- NeoGenomics
- Pacific Biomarkers
- Pathway Genomics
- Quest Diagnostics
- Syngenta
- Synthetic Genomics

States that are Both Large and Specialized*

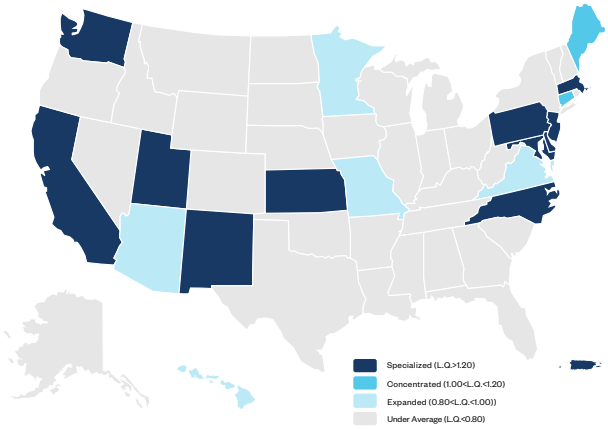
- California
- Massachusetts
- New Jersey
- Pennsylvania
- North Carolina

**States are listed in descending order by subsector employment levels.*

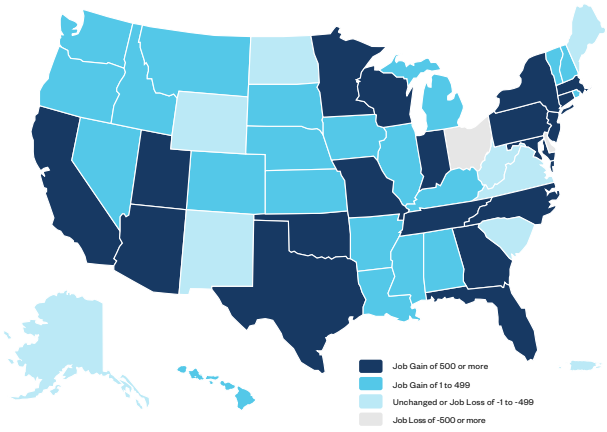
State Share of Total U.S. Employment
2016



Employment Concentration Relative to the U.S.
2016



Employment Gains and Losses
2014-2016



Research, Testing & Medical Laboratories

State Leaders & Highlights

Employment Size: With the largest employment base and the highest overall growth rate among the five subsectors, the research, testing and medical labs subsector has a significant presence in most states. The top ten employer states make up 64 percent of national employment, and the top 15 all have more than 10,000 subsector jobs.

- **Large States**: California, Massachusetts, New Jersey, Pennsylvania, North Carolina
- **Sizable States**: New York, Florida, Texas, Maryland, Illinois

Employment Concentration: Eleven states and Puerto Rico have a specialized concentration of jobs in the research, testing and medical laboratories subsector.

- **Specialized States**: Massachusetts, New Jersey, Maryland, Delaware, North Carolina, Puerto Rico, New Mexico, California, Utah, Pennsylvania, Washington, Kansas
- **Concentrated States**: District of Columbia, Connecticut, Maine

Employment Growth: Over the 2014 to 2016 period, 39 states experienced some increase in subsector employment. Nineteen states experienced substantial increases led by California, New Jersey, Massachusetts, Pennsylvania, Texas, North Carolina and Florida.

Large and Specialized States: Five states have both high employment and a specialized concentration of jobs in research, testing and medical laboratories (Table 16).

Table 17

Metropolitan Statistical Areas with the Largest Employment Levels in Research, Testing and Medical Laboratories, 2016

Metropolitan Statistical Area	2016 Employment
New York-Newark-Jersey City, NY-NJ-PA	47,090
Boston-Cambridge-Newton, MA-NH	46,375
San Francisco-Oakland-Hayward, CA	25,099
San Diego-Carlsbad, CA	24,647
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	24,048
Los Angeles-Long Beach-Anaheim, CA	22,569
Washington-Arlington-Alexandria, DC-VA-MD-WV	19,504
Chicago-Naperville-Elgin, IL-IN-WI	16,402
San Jose-Sunnyvale-Santa Clara, CA	11,750
Durham-Chapel Hill, NC	9,765
Seattle-Tacoma-Bellevue, WA	9,699
Miami-Fort Lauderdale-West Palm Beach, FL	8,835
Baltimore-Columbia-Towson, MD	8,343
Minneapolis-St. Paul-Bloomington, MN-WI	8,143
Dallas-Fort Worth-Arlington, TX	7,361
Kansas City, MO-KS	7,229
Phoenix-Mesa-Scottsdale, AZ	7,062
Salt Lake City, UT	6,661
Atlanta-Sandy Springs-Roswell, GA	6,503
St. Louis, MO-IL	6,380
Houston-The Woodlands-Sugar Land, TX	6,270
Pittsburgh, PA	5,765
Raleigh, NC	5,381
Detroit-Warren-Dearborn, MI	5,031
Madison, WI	4,976

Table 16

States with Large and Specialized Employment in Research, Testing and Medical Laboratories, 2016

State	Establishments, 2016	Employment, 2016	Location Quotient, 2016	Share of U.S. Employment
California	4,221	94,348	1.47	17.2%
Massachusetts	1,637	51,202	3.69	9.4%
New Jersey	1,072	35,600	2.34	6.5%
Pennsylvania	1,303	29,588	1.29	5.4%
North Carolina	1,862	28,896	1.79	5.3%

Table 18

Metropolitan Statistical Areas with the Highest Location Quotients in Research, Testing and Medical Laboratories, by size of MSA, 2016

Metropolitan Statistical Area	Location Quotient	2016 Employment
Large MSAs (Total Private Employment Greater than 250,000		
San Diego-Carlsbad, CA	4.44	24,647
Boston-Cambridge-Newton, MA-NH	4.27	46,375
Madison, WI	3.52	4,976
San Francisco-Oakland-Hayward, CA	2.64	25,099
San Jose-Sunnyvale-Santa Clara, CA	2.56	11,750
Salt Lake City, UT	2.47	6,661
Raleigh, NC	2.27	5,381
Albuquerque, NM	2.15	3,011
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2.11	24,048
Worcester, MA-CT	2.06	3,132
Greensboro-High Point, NC	2.00	2,944
Kansas City, MO-KS	1.74	7,229
Washington-Arlington-Alexandria, DC-VA-MD-WV	1.73	19,504
Albany-Schenectady-Troy, NY	1.63	2,623
Baltimore-Columbia-Towson, MD	1.60	8,343
Medium MSAs (Total Private Employment Between 75,000 and 250,000)		
Durham-Chapel Hill, NC	8.88	9,765
Trenton, NJ	5.52	4,661
Kennewick-Richland, WA	4.55	2,106
Wilmington, NC	4.13	1,944
Barnstable Town, MA	2.15	825
Boulder, CO	2.13	1,469
Spokane-Spokane Valley, WA	1.86	1,639
Ann Arbor, MI	1.67	1,026
St. Cloud, MN	1.41	599
Norwich-New London, CT	1.33	582
Gainesville, FL	1.31	590
Lincoln, NE	1.30	867
South Bend-Mishawaka, IN-MI	1.29	715
Huntsville, AL	1.27	1,012
Peoria, IL	1.23	873
Small MSAs (Total Private Employment Less than 75,000)		
Burlington, NC	11.63	2,924
Ames, IA	3.19	462
California-Lexington Park, MD	2.51	347
Morgantown, WV	2.38	565
Mount Vernon-Anacortes, WA	2.34	420
Ithaca, NY	1.76	367
Logan, UT-ID	1.59	334
Columbia, MO	1.52	483
Santa Fe, NM	1.25	271
Lafayette-West Lafayette, IN	1.23	414
Manhattan, KS	1.22	162
Lewiston, ID-WA	1.17	122
Brunswick, GA	1.14	182
Bangor, ME	1.12	300
Idaho Falls, ID	1.09	283

Bioscience-Related Distribution

The bioscience-related distribution subsector coordinates the delivery of bioscience-related products spanning pharmaceuticals, medical devices and equipment and ag biotech products. The subsector leverages and deploys specialized technologies such as cold storage, highly regulated product monitoring, RFID technologies and automated drug distribution systems.

Examples of Products

Distribution of:

- Pharmaceuticals
- Vaccines
- Plasma/blood
- Veterinary medicines
- Surgical instruments/appliances
- Diagnostic and bioimaging equipment
- Plant seeds
- Agricultural chemicals

Examples of Companies

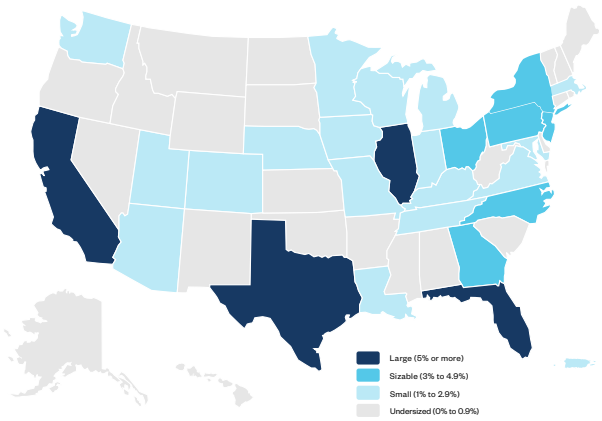
- Amerisource-Bergen
- Cardinal Health
- Henry Schein
- McKesson
- Monsanto
- Omnicare
- Owens & Minor
- Park Seed
- Patterson Companies
- PharMerica Corporation
- Seminis Vegetable Seeds
- Wilbur-Ellis

States that are Both Large and Specialized*

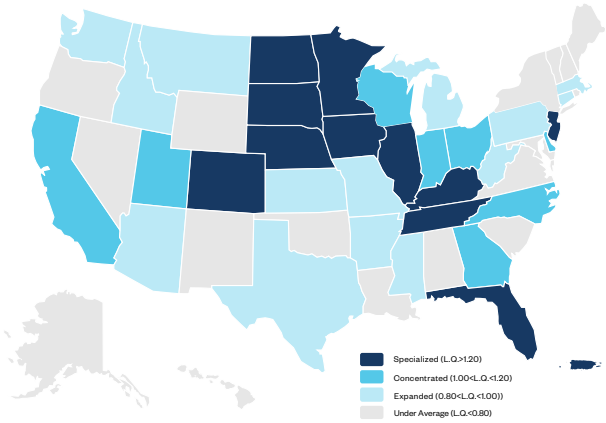
- Florida
- Illinois

**States are listed in descending order by subsector employment levels.*

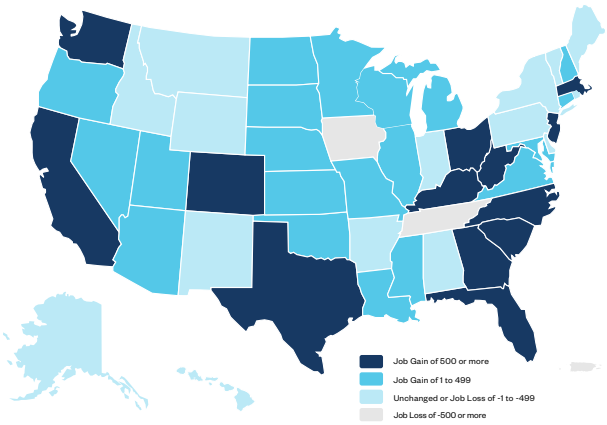
State Share of Total U.S. Employment
2016



Employment Concentration Relative to the U.S.
2016



Employment Gains and Losses
2014-2016



Bioscience-Related Distribution

State Leaders & Highlights

Employment Size: The distribution subsector's large employment base is well distributed across the U.S., with the top 10 employing states making up just 55 percent of all employment and every state having a presence to some degree.

- **Large States:** California, Texas, Florida, Illinois
- **Sizable States:** New Jersey, New York, Ohio, Pennsylvania, North Carolina, Georgia

Employment Concentration: Eleven states and Puerto Rico have a specialized concentration of jobs in the bioscience-related distribution subsector.

- **Specialized States**: Nebraska, South Dakota, Puerto Rico, North Dakota, Iowa, New Jersey, Tennessee, Illinois, Florida, Kentucky, Colorado, Minnesota
- **Concentrated States**: North Carolina, Wisconsin, Ohio, Utah, Delaware, California, Georgia, Indiana

Employment Growth: Over the 2014 to 2016 period, 33 states experienced some increase in subsector employment with 13 states having substantial increases led by Texas, California, Georgia, Massachusetts, Florida, New Jersey and Ohio.

Large and Specialized States: Two states have both high employment and a specialized concentration of jobs in bioscience-related distribution (Table 19).

Table 20

Metropolitan Statistical Areas with the Largest Employment Levels in Bioscience-Related Distribution, 2016

Metropolitan Statistical Area	2016 Employment
New York-Newark-Jersey City, NY-NJ-PA	32,883
Los Angeles-Long Beach-Anaheim, CA	25,251
Chicago-Naperville-Elgin, IL-IN-WI	20,494
Dallas-Fort Worth-Arlington, TX	17,439
Miami-Fort Lauderdale-West Palm Beach, FL	15,595
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	11,005
Atlanta-Sandy Springs-Roswell, GA	10,633
Houston-The Woodlands-Sugar Land, TX	8,197
Boston-Cambridge-Newton, MA-NH	8,169
Minneapolis-St. Paul-Bloomington, MN-WI	7,908
Phoenix-Mesa-Scottsdale, AZ	6,774
Denver-Aurora-Lakewood, CO	6,692
Columbus, OH	6,092
Riverside-San Bernardino-Ontario, CA	5,624
Detroit-Warren-Dearborn, MI	5,387
Memphis, TN-MS-AR	5,279
San Francisco-Oakland-Hayward, CA	5,225
Seattle-Tacoma-Bellevue, WA	5,132
St. Louis, MO-IL	4,845
San Diego-Carlsbad, CA	4,690
Nashville-Davidson—Murfreesboro—Franklin, TN	4,521
Tampa-St. Petersburg-Clearwater, FL	4,503
Indianapolis-Carmel-Anderson, IN	4,341
Charlotte-Concord-Gastonia, NC-SC	4,333
Cincinnati, OH-KY-IN	4,285

Table 19

States with Large and Specialized Employment in Bioscience-Related Distribution, 2016

State	Establishments, 2016	Employment, 2016	Location Quotient, 2016	Share of U.S. Employment
Florida	3,018	36,155	1.28	7.7%
Illinois	1,881	26,058	1.31	5.5%

Table 21

Metropolitan Statistical Areas with the Highest Location Quotients in Bioscience-Related Distribution, by size of MSA, 2016

Metropolitan Statistical Area	Location Quotient	2016 Employment
Large MSAs (Total Private Employment Greater than 250,000		
Memphis, TN-MS-AR	2.48	5,279
Des Moines-West Des Moines, IA	2.01	2,454
Oxnard-Thousand Oaks-Ventura, CA	1.92	2,112
Raleigh, NC	1.85	3,717
Columbus, OH	1.79	6,092
Miami-Fort Lauderdale-West Palm Beach, FL	1.76	15,595
Louisville/Jefferson County, KY-IN	1.63	3,626
Jacksonville, FL	1.61	3,667
Columbia, SC	1.60	1,886
Dallas-Fort Worth-Arlington, TX	1.47	17,439
Nashville-Davidson—Murfreesboro—Franklin, TN	1.42	4,521
Greensboro-High Point, NC	1.42	1,765
Denver-Aurora-Lakewood, CO	1.38	6,692
Toledo, OH	1.36	1,392
Omaha-Council Bluffs, NE-IA	1.32	2,170
Medium MSAs (Total Private Employment Between 75,000 and 250,000)		
Port St. Lucie, FL	3.54	1,718
Naples-Immokalee-Marco Island, FL	2.92	1,519
Springfield, IL	2.41	792
Provo-Orem, UT	2.11	1,606
Visalia-Porterville, CA	1.88	975
Trenton, NJ	1.77	1,267
Kalamazoo-Portage, MI	1.74	856
Fargo, ND-MN	1.58	745
Lakeland-Winter Haven, FL	1.55	1,148
Fort Collins, CO	1.53	736
Greeley, CO	1.49	499
Santa Cruz-Watsonville, CA	1.47	502
Sioux Falls, SD	1.43	762
Stockton-Lodi, CA	1.40	1,111
Boulder, CO	1.35	794
Small MSAs (Total Private Employment Less than 75,000)		
Albany, OR	4.61	695
El Centro, CA	3.49	627
Morgantown, WV	3.32	670
Jackson, TN	2.56	534
Hammond, LA	2.32	297
Ames, IA	2.26	277
Jonesboro, AR	2.10	389
Bloomington, IN	1.85	369
Yuma, AZ	1.67	342
Hanford-Corcoran, CA	1.64	207
Texarkana, TX-AR	1.59	293
Iowa City, IA	1.53	373
Grand Island, NE	1.49	212
Cape Girardeau, MO-IL	1.40	212
Danville, IL	1.36	119

THE INNOVATION ECOSYSTEM: STATE PERFORMANCE MEASURES

This section highlights leading states—both overall and on a per capita basis—across performance measures for the bioscience industry's innovation ecosystem, including:

- National Institutes of Health funding
- Academic bioscience R&D expenditures
- Bioscience-related patents
- Venture capital investments in bioscience companies

Academic Bioscience R&D Expenditures

Academic research, funded through federal and other sources including industry, non-profits and state and local governments, is a major force for life sciences innovation. U.S. colleges and universities spent $42 billion in bioscience-related R&D activities in 2016. The leading states are generally larger and home to multiple research universities. Five of these states exceeded $2 billion in 2016 expenditures—California, New York, Texas, Pennsylvania and North Carolina (Table 22). Pennsylvania and Massachusetts are not only among the leaders in overall size but also in terms of recent growth.

On a per capita basis, other states emerge among the leaders including Washington, DC (which includes two major research universities), Connecticut, Nebraska, New Hampshire and Iowa (Table 23). Other states have a very high concentration of their academic R&D activity focused in the biosciences including Missouri, Vermont, Arkansas and Connecticut, which all exceed 80 percent of their overall expenditures.

Table 22
Leading States-Academic Bioscience R&D Expenditures & Growth

Academic Bioscience R&D Expenditure, 2016	
Leading States	**Total R&D Expenditure ($ Thousands)**
California	$5,539,463
New York	$4,057,179
Texas	$3,276,218
Pennsylvania	$2,425,134
North Carolina	$2,159,908
Massachusetts	$1,723,143
Maryland	$1,708,746
Illinois	$1,429,861
Ohio	$1,344,444
Michigan	$1,336,071

Academic Bioscience R&D Growth, 2014-16	
Leading States	**Growth Rate, %**
Wyoming	135.2%
Alaska	24.1%
Colorado	21.8%
Montana	18.2%
Nevada	17.8%
Pennsylvania	17.6%
Arizona	15.0%
Alabama	14.8%
Connecticut	14.6%
Massachusetts	13.7%

Source: TEConomy Partners analysis of National Science Foundation (NSF) Higher Education Research and Development (HERD) Survey.

Table 23
Leading States-Per Capita and Concentration of Academic Bioscience R&D Expenditures

Academic Bioscience R&D Per Capita, 2016	
Leading States	**$ Per Capita**
District of Columbia	$457
Maryland	$284
Connecticut	$256
Massachusetts	$253
North Carolina	$213
New York	$205
Pennsylvania	$190
Nebraska	$176
New Hampshire	$166
Iowa	$164

Academic Bioscience Share of Total Science & Engineering R&D	
Leading States	**% Share**
Missouri	84.6%
Vermont	81.8%
Arkansas	80.8%
Connecticut	80.2%
Kentucky	78.2%
North Carolina	75.9%
Nebraska	75.0%
South Carolina	72.6%
Minnesota	71.9%
Oregon	70.3%

Source: TEConomy Partners analysis of National Science Foundation (NSF) Higher Education Research and Development (HERD) Survey.

NIH Funding

The recent growth in NIH budgets and corresponding research grants represent a welcome infusion to the innovation ecosystem following many years of flat or declining federal funding for bioscience research. Institutions and researchers in seven states exceeded $1 billion in NIH funding in 2017 (Table 24) and an eighth state, Washington, was on the cusp. Leading recipients in smaller states such as Massachusetts and Maryland are highly concentrated relative to the state's population and reach three to five times the national average ($80 per capita). And while the original base level of state funding can influence or overstate recent growth rates, Maryland is again near the top of the list, rapidly growing a large existing base. Rhode Island is highly concentrated in funding relative to its size and is growing rapidly.

Table 24
Leading States-NIH Funding

Total NIH Funding, 2017		Per Capita NIH Funding, 2017		NIH Funding Growth, 2014-17	
Leading States-NIH Funding	**Total Funding ($ Thousands)**	**Leading States-NIH Funding**	**$ Per Capita**	**Leading States-NIH Funding**	**Growth Rate, 2014-17**
California	$3,946,355	Massachusetts	$396	Wyoming	66.1%
Massachusetts	$2,716,744	District of Columbia	$328	Maryland	59.4%
New York	$2,386,045	Maryland	$266	Alaska	55.7%
Pennsylvania	$1,672,905	Rhode Island	$161	Mississippi	50.9%
Maryland	$1,611,923	Connecticut	$146	West Virginia	49.2%
North Carolina	$1,245,779	Washington	$135	Florida	37.4%
Texas	$1,160,645	Pennsylvania	$131	Virginia	34.6%
Washington	$998,184	North Carolina	$121	Idaho	32.0%
Illinois	$805,535	New York	$120	Rhode Island	29.4%
Ohio	$754,319	Minnesota	$100	Arkansas	29.0%

Source: TEConomy Partners analysis of National Institutes of Health RePORT data.

Bioscience-Related Patents

U.S. inventors were associated with nearly 103,000 patents awarded from 2014 through 2017 in bioscience-related technology classes. California is, by far, the leading state in patent awards accounting for nearly one in three patents during the 4-year period (Table 25). Massachusetts also stands out in generating close to 12,000 patents and leads among states in per capita patent awards. Several states not among the national leaders show innovation strengths relative to their size including Delaware, Connecticut, New Hampshire, Rhode Island, Indiana and Maryland.

Table 26 provides insights into the innovation strengths of leading states. Several states, such as California, Pennsylvania, Massachusetts, Illinois, New York and New Jersey are among the leaders in all, or nearly all categories reflecting varied and wide-reaching industry and university innovation strengths. Other states such as Iowa, Indiana, Missouri, North Carolina, Washington and Wisconsin demonstrate more focused niche strengths in one or two predominant technology areas.

Table 25
Leading States-Bioscience-Related Patents

Bioscience-Related Patent Totals, 2014-17	
Leading States	**Count**
California	30,386
Massachusetts	11,699
New Jersey	7,303
Pennsylvania	7,029
New York	6,977
Minnesota	6,813
Florida	5,100
Texas	4,704
Ohio	4,553
Illinois	4,355

Bioscience-Related Patent Distributions	
Leading States	**Per 1M Population**
Massachusetts	429
Minnesota	309
Delaware	249
Connecticut	243
New Hampshire	230
New Jersey	204
California	194
Rhode Island	170
Indiana	157
Maryland	153

Source: TEConomy Partners analysis of U.S. Patent & Trademark Office data from Clarivate Analytics' Derwent Innovation patent analysis database.

Table 26
Leading States-Bioscience-Related Patents by Class Group, 2014-2017

State	Total Bioscience Patents	Agricultural Biosciences	Biochemistry	Bioinformatics & Health IT	Biological Sampling & Analysis	Drugs & Pharmaceuticals	Medical & Surgical Devices	Microbiology & Genetics
CA	●	●	●	●	●	●	●	●
FL	○	○		○	○	○	●	
IA		●	○					
IL	○	●	●	●	○			○
IN		●	○				○	
MA	●		●	●	●	●	●	●
MD			○		●	○		●
MN	○	●	○	○			●	
MO		○		●				
NC						○		○
NJ	●		●		●	●	○	○
NY	●		○	●	●	●	○	●
OH	○	○			○	○	●	
PA	●	○	●	○	○	●	○	●
TX	○			○	○	○	○	○
WA				○				
WI		○						○

Source: TEConomy Partners analysis of U.S. Patent & Trademark Office data from Clarivate Analytics' Derwent Innovation patent analysis database.

Note: A shaded circle signifies the state ranks in the top 5 and an open circle signifies the state ranks in the next 5 for that particular patent class.

Bioscience Venture Capital Investments

Venture capital investments in U.S. bioscience companies are rising and reached a new high at $20 billion in 2017. Despite this expansion, venture investments continue to be highly concentrated in two states—California and Massachusetts. Combined, companies in these states were recipients of nearly $44 billion in VC investments during the 2014 to 2017 period, capturing 66 percent of the national total, or $2 out of every $3 invested. Eleven states have had more than $1 billion in VC investments during the last four years—the ten states shown in Table 27 plus New Jersey.

Beyond Massachusetts and California, Washington, Pennsylvania and Minnesota stand out for attracting $1 to nearly $2 billion in VC investments relative to the size of their states.

The leading states in venture capital investments by industry/technology segment are shown in Table 28. Massachusetts and California are among the leading states in nearly all categories. Texas, Pennsylvania and New York are among the leaders in six (TX, PA) and five (NY) categories, respectively.

Table 27
Leading States in Bioscience Venture Capital Investments

Total Bioscience Venture Capital Investment, 2014-17	
Leading States	**Total ($ Millions)**
California	$28,582
Massachusetts	$15,270
New York	$2,158
Washington	$1,993
Pennsylvania	$1,778
Texas	$1,591
Illinois	$1,586
North Carolina	$1,368
Colorado	$1,180
Minnesota	$1,132

Bioscience Venture Capital Distributions	
Leading States	**$ Per 1M Population**
Massachusetts	$2,226
California	$723
Washington	$269
Connecticut	$250
Colorado	$210
Minnesota	$203
Utah	$200
District of Columbia	$159
Maryland	$158
Pennsylvania	$139

Source: TEConomy Partners analysis of data from PitchBook Data, Inc.

Table 28
Leading States in Bioscience Venture Capital Investments by Segment, 2014-2017

State	Agricultural Chemicals	Biofuels	Biotechnology	Diagnostic Equipment	Drug Discovery and Delivery	Healthcare Distributors	Healthcare Technology Systems	Laboratory Services (Healthcare)	Medical Supplies	Monitoring Equipment	Other Biosciences and Healthcare	Pharmaceuticals	Surgical Devices	Therapeutic Devices
MA	●	●	●	●	●		●	●	●	●	●	●	●	●
CA		●	●	●	●		●	●	●	●	●	●	●	●
TX				●	●	●		●			●			●
NY			●				●	●	●	●				
PA		●		●	●							●	●	●
IL		●			●		●					●		
FL	●					●				●			●	
WA			●	●										
CO	●	●					●		●					
MN													●	●
NC			●							●				
GA									●		●			
MI	●					●								
NJ												●		
OH											●			
IN						●								
MD	●													
MO								●						
NV						●								

Source: TEConomy Partners analysis of data from PitchBook Data, Inc.

APPENDIX: DATA & METHODOLOGY

Industry Employment, Establishments and Wages

The bioscience industry employment analysis in this report examines national, state and metropolitan area data and corresponding trends in the biosciences from 2001 through 2016. For employment analysis, TEConomy Partners used the Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) data. The QCEW data provide the most current, detailed industry employment, establishment and wage figures available at both a national and subnational level. TEConomy utilizes an enhanced version of these data from a private vendor, IMPLAN.

The QCEW program is a cooperative program involving BLS and the State Employment Security Agencies. The QCEW program produces a comprehensive tabulation of employment and wage information for workers covered by state unemployment insurance (UI) laws and federal workers covered by the Unemployment Compensation for Federal Employees (UCFE) program. Publicly available files include data on the number of establishments, monthly employment and quarterly wages, by NAICS (North American Industry Classification System) industry, by county and by ownership sector, for the entire United States. These data are aggregated to annual levels, to higher industry levels (NAICS industry groups, sectors and supersectors) and to higher geographic levels (national, state and metropolitan statistical area [MSA]).

Since 2001, the QCEW has been producing and publishing data according to the NAICS. Compared with the prior classification system—the 1987 Standard Industrial Classification (SIC) system, NAICS better incorporates new and emerging industries. Employment, establishment and wage data produced by the QCEW program for 2001 to present are not comparable with SIC-based industry data from prior years. This limits the ability to construct a longer time series for data analysis; however, 16 years of NAICS-based data (2001-2016) are now available.

Twenty-four NAICS industries at the most detailed (6-digit) level make up the TEConomy definition of the biosciences and its subsectors. These detailed industries are aggregated up to five major subsectors of the bioscience industry. Four of the detailed NAICS

industries, Testing Laboratories (NAICS 541380); R&D in the Physical, Engineering and Life Sciences (except Biotechnology) (NAICS 541712); Drug and Druggists' Sundries Merchant Wholesalers (NAICS 424210); and Farm Supplies Merchant Wholesalers (NAICS 424910) are adjusted in this analysis by TEConomy to include only the share of these industries directly involved in biological or other life science activities. To isolate these relevant life science components, TEConomy used information and data from the U.S. Census Bureau's Economic Census. These shares were updated by TEConomy for this edition of the biennial report and applied historically, and therefore data for the relevant industry subsectors are no longer comparable with those published in prior reports.

Table A-1.
The Bioscience Industry, NAICS Definition

Bioscience Subsector	NAICS Code	NAICS Description
Agricultural Feedstock & Industrial Biosciences		
	311221	Wet Corn Milling
	311224	Soybean and Other Oilseed Processing
	325193	Ethyl Alcohol Manufacturing
	325311	Nitrogenous Fertilizer Manufacturing
	325312	Phosphatic Fertilizer Manufacturing
	325314	Fertilizer (Mixing Only) Manufacturing
	325320	Pesticide and Other Agricultural Chemical Manufacturing
Drugs & Pharmaceuticals		
	325411	Medicinal and Botanical Manufacturing
	325412	Pharmaceutical Preparation Manufacturing
	325413	In-Vitro Diagnostic Substance Manufacturing
	325414	Biological Product (except Diagnostic) Manufacturing
Medical Devices & Equipment		
	334510	Electromedical and Electrotherapeutic Apparatus Manufacturing
	334516	Analytical Laboratory Instrument Manufacturing
	334517	Irradiation Apparatus Manufacturing
	339112	Surgical and Medical Instrument Manufacturing
	339113	Surgical Appliance and Supplies Manufacturing
	339114	Dental Equipment and Supplies Manufacturing
Research, Testing, & Medical Laboratories		
	541380*	Testing Laboratories
	541711	Research and Development in Biotechnology
	541712*	Research and Development in the Physical, Engineering and Life Sciences (except Biotechnology)
	621511	Medical Laboratories
Bioscience-Related Distribution		
	423450	Medical, Dental and Hospital Equipment and Supplies Merchant Wholesalers
	424210*	Drugs and Druggists' Sundries Merchant Wholesalers
	424910*	Farm Supplies Merchant Wholesalers

**Includes only the portion of these industries engaged in relevant life science activities.*

National and state data were tabulated and presented in both summary analytical and state profile tables. Data for Puerto Rico and the District of Columbia are included in this report at both the "state" and national level. U.S. employment, establishment and wage totals in this report reflect the sum of all state data and include both Puerto Rico and DC. All state, DC and most data for Puerto Rico are from TEConomy's enhanced QCEW file from IMPLAN.

For more information on the BLS Quarterly Census of Employment and Wages, see http://www.bls.gov/cew/.

Industry Economic Impacts and Employment Multipliers

The economic impact of the U.S. bioscience industry is estimated using national employment at a detailed industry sector level as inputs; and was developed using a custom national Input/Output (I/O) model from IMPLAN. The IMPLAN model's data matrices track the flow of commodities to industries from producers and institutional consumers within the nation. The data also model consumption activities by workers, owners of capital and imports. The inter-industry trade flows built into the model permit estimating the impacts of one sector on all other sectors with which it interacts. The model's outputs, which are the impacts typically measured in an economic impact study, are the expenditure impacts of the bioscience industry. They quantify direct and indirect job creation, associated personal incomes, business output and associated revenues to federal, state and local taxing jurisdictions.

Separately, employment multipliers generated from IMPLAN's state level Input/Output models were used to estimate the employment impact on all other industries of adding bioscience jobs at the state level. It is important to note that, like all impact models, Input/Output models provide an approximate order-of-magnitude estimate of impacts. State level multipliers and the resulting estimated employment impacts are shown in each state profile table for each major bioscience subsector.

Additional Bioscience Performance Metrics Data

At the national level and for each of the state profiles, additional key bioscience performance metrics provide further insights into the current structure, recent performance and capacity of the state's bioscience innovation ecosystem. These metrics and their data sources are briefly described in the following paragraphs.

Bioscience Academic R&D Expenditures

Based upon data from the National Science Foundation's (NSF) Higher Education Research and Development Survey, national and state totals (summation of all state's responding institutions) are calculated for FY 2016 (most current year available) as well as the previous two years (FY 2014 – FY 2015). Data are provided for total R&D expenditures (including per capita measures) as well as in chart form for the bioscience fields including Health Sciences, Biological and Biomedical Sciences, Agricultural Sciences, Bio/Biomedical Engineering, Natural Resources and Conservation and Other Life Sciences.

For more information on the NSF Higher Education Research and Development Survey, see http://www.nsf.gov/statistics/srvyherd/.

National Institutes of Health (NIH) Funding

NIH extramural funding data for FY 2017 (the most current full year available) and for previous years were obtained using the NIH Awards by Location &

Organization section within the NIH Research Portfolio Online Reporting Tool (RePORT) database. Data are provided for total NIH extramural funding, growth from FY 2014 through FY 2017 and FY 2017 per capita measures are also calculated.

For more information on the NIH Awards data, see http://report.nih.gov/award/index.cfm.

Bioscience Venture Capital Investments

Venture capital investments, while not the only source of equity capital for bioscience firms, are often the largest and is typically the most publicly known and reported source of investment funds allowing for comparability among states.

Venture capital data were collected using the PitchBook venture capital database capturing all venture capital (including "Angel" and pre-seed investment activity) from January 1, 2014 through December 31, 2017. The analysis includes selected investments categorized in PitchBook in the Healthcare industry sector, including all companies in Healthcare Devices and Supplies, Healthcare Technology Systems, Pharmaceuticals and Biotechnology and Other Healthcare. Only Healthcare Distributors and Laboratory Services companies are included from PitchBook's Healthcare Services industry group; but the analysis excludes hospitals, clinics, elder care facilities and other healthcare service companies. Investments in Agricultural Chemicals within PitchBook's Materials and Resources industry sector were also included. Additionally, specific investments in venture capital deals related to ethanol/biofuel/biodiesel-related companies were included from the Alternative Energy Equipment and Energy Production industry codes located within the Energy sector in PitchBook.

Bioscience Patents

The use of patent data provides a surrogate (though not perfect) approach to understanding those innovations that bioscience-related industrial organizations, research institutions and general inventors deem significant enough to register and protect. Patents provide some measure of comparability among regions in one facet of innovation in terms of activity levels within distinct technology areas. Furthermore, examining recent patent activity provides some insight into firms' recent R&D investment areas and strategies, and hence, potential future lines of business.

Each patent document references at least two distinct entities who are associated with the intellectual property (IP) that was generated—the inventor(s) of the patent, or the person(s) who generated the IP disclosed in the patent, and the assignee(s) of the patent, or the entity(ies) which currently have ownership of the IP outlined in the patent. Each patent can have multiple inventors and assignees, and multiple inventors are very common. For this analysis, TEConomy uses the address location of the named inventor(s) in the analysis of geographic distribution of bioscience patent areas across states, with the credit for invention being "shared" across all the unique states represented by the set of listed inventors in the patent document. Hence, if a bioscience patent is invented by individuals in two states, each state will receive "credit" for generating the patent, but at a national level the patent is counted only once. Similarly, when two or more named inventors are from the same state the patent only gets counted once.

It is important to note that this analysis uses only the inventors of the patent as a measure of bioscience innovation activity levels. As companies acquire

ownership of IP being generated by others, patents can be assigned to different geographies without any addition of significant innovative value to the original patent. As a result, tracking patent innovation levels by inventor allows for a more consistent and accurate assessment of the places where innovative bioscience IP is being generated by researchers as opposed to being retained or licensed by companies which may or may not align with the same geographic context.

USPTO assigns each patent with a specific numeric major patent "class" as well as supplemental secondary patent classes which detail the primary technology areas being documented by the patented IP. These classes are assigned to patents by dedicated classification staff who examine the documented IP's key focus and end uses. For example, a patent for a new biopharmaceutical may have a main patent class detailing the therapeutic activity or formulation of the drug with supplemental classes documenting any novel synthesizing or manufacturing processes critically tied to creation of the drug. The major patent class and supplemental patent classes are chosen by the USPTO classification staff during the process of reviewing patent applications. By combining relevant patent classes across the wide array of bioscience-related activity, these class designations allow for an aggregation scheme that focuses around broad technology themes that are specific to the biosciences. TEConomy has grouped US-invented patents into broader bioscience patent class groups for the purposes of bioscience innovation trends analysis.

Beginning in 2010, the UPSTO and the European Patent Office (EPO) began the process of moving towards a Cooperative Patent Classification (CPC) system enacted as a harmonization and compatibility effort to provide consistent technology class documentation of disclosed IP across international borders. The new class system uses a structure that is similar to and complies with the International Patent Classification (IPC) system but expands on it in documenting detailed new technology areas. TEConomy uses this CPC scheme to group US-invented patents into broader bioscience patent class groups for the purposes of bioscience innovation trends analysis.

Patent data were collected using the Clarivate Analytics' Derwent Innovation patent analysis database and includes all granted patents from January 1, 2014 through December 31, 2017 as documented by USPTO. Table A-2 provides a listing of the patent classes and class groups that were used in this analysis to determine the set of bioscience-related patents as well as how they are grouped into major areas of bioscience-related technologies.

Table A-2
Bioscience-Related Patents—Classes and Groups

Bioscience Patent Class Group	Patent Class	Patent Class Description
Agricultural Bioscience		
	A01H	New plant varieties, cultivars, genotypes and processes for engineering them
	A01N	Preservation of human or animal bodies and plants, biocides/pesticides and plant growth regulators
	C05B	Phosphatic fertilizers
	C05C	Nitrogenous fertilizers
	C05D	Inorganic fertilizers
	C05F	Organic fertilizers
	C05G	Fertilizer mixtures
Biochemistry		
	C07D	Organic chemistry (heterocyclic compounds)
	C07H	Sugars and derivatives thereof; nucleosides; nucleotides; nucleic acids
	C07J	Steroids
	C07K	Peptides
Bioinformatics & Health IT		
	G06F 19/1, 19/2	Bioinformatics
	G06F 19/3	Medical informatics and clinician decision support tools
	G06Q 50/22	General health IT systems and software
	G06Q 50/24	Patient record data management
Biological Sampling & Analysis		
	G01N 24	Assays (e.g. immunoassays or enzyme assays)
	G01N 25	Screening methods for compounds of potential therapeutic value
	G01N 26	Assays involving molecular polymers
	G01N 28	Detection or diagnosis of specific diseases
	G01N 33 (partial)	Investigation and analysis techniques pertaining to specific biological substances
	G01R 33 (partial)	NMR spectroscopy analysis of biological material (e.g. in vitro testing) and NMR imaging systems
Drugs & Pharmaceuticals		
	A61K	Pharmaceuticals, biopharmaceuticals and biologics
Medical & Surgical Devices		
	G06K 9 (partial)	Microscopic inspection of biological structures
	G06T 7 (partial)	Biomedical image processing and analysis

Table A-2
Bioscience-Related Patents—Classes and Groups

Bioscience Patent Class Group	Patent Class	Patent Class Description
	A61B	Surgical and diagnostic devices
	A61C	Dental instruments, implements, tools or methods
	A61D	Veterinary instruments, implements, tools or methods
	A61F	Orthopedic and prosthetic equipment, implantable devices (e.g. stents), bandages and first aid devices and other medical supplies
	A61G	Medical transport devices, operating chairs and tables for medical/dental patient applications
	A61H	Physical therapy apparatus, artificial respiration
	A61J	Containers and devices for administering pharmaceuticals, medicine and food and other medical materials; baby comforters
	A61L	Sterilizing/deodorization of materials; chemical materials for bandages, dressings and other surgical articles
	A61M	Devices for introducing or removing media from the body; devices for producing or ending sleep/stupor
	A61N	Electrotherapy; magnetotherapy; radiation therapy; ultrasound therapy
Microbiology & Genetics		
	C12M	Enzymology or microbiology equipment and devices
	C12N	Genetic engineering, culture media and other microbiology methods or compositions
	C12P	Fermentation or enzyme-related synthesis of chemical compounds
	C12Q	Measuring or testing processes involving enzymes or microbiology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