

Labor Market Analysis for Cell and Gene Therapy Technician Workforce



Prepared by John Carrese
For NIIMBL Project 2.2-152
WEBET: Workforce Expansion in Biomanufacturing Emerging Technologies
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About NIIMBL and WE-BET

This project was developed with an award from the National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) and financial assistance from the U.S. Department of Commerce, National Institute of Standards and Technology (70NANB17H002). NIIMBL is one of 16 Manufacturing USA Institutes that establishes networks of public-private partnerships that work with academic and private sector manufacturing organizations on research and development and manufacturing skills training. Each institute focuses on a particular advanced manufacturing specialty such as biomanufacturing.

The Workforce Expansion in Biomanufacturing Emerging Technologies (WE-BET) initiative (Project Call 2.2-152) addresses the challenge of expanding the workforce that will produce cell-based and gene therapies. It utilizes an existing decades-long collaboration network of community and technical colleges to develop and deliver curriculum that will enable educators at hundreds of colleges across the United States to teach the knowledge and skills that will prepare a graduate to enter these emerging fields.

The Need for Labor Market Research

Little research currently exists at the national, state or regional level on the cell and gene therapy (CGT) technician workforce and the demand for these workers in this fast growing industry. Utilizing existing programs to build this workforce should prevent a worker shortage from hampering the expansion of these important treatments. Also, the competitiveness of the United States in these biopharmaceutical fields will be based on the presence of people with the appropriate expertise. This seems to appropriately match **the NIIMBL goal of assuring a sufficient workforce in the manufacture of biologics.**

Recent references, meetings, and communication with industry indicate the expansion in cell-based therapies and gene therapies will be dramatic. If some projections are correct, the scale of this expansion threatens to strain the capacity of the existing workforce.

This report seeks to answer the question: **“What is the labor market demand for CGT technicians in the near term, mid-term, and long- term?”** While projections have been difficult to come by, every indication suggests that the workforce size will certainly be big enough to justify this project. **And without a major effort, these same indications suggest that there might be a looming crisis.** At a recent meeting, **the NIIMBL Workforce committee identified workforce forecasting as a real challenge and need.** The committee acknowledged that these data have been difficult to generate.

Gathering labor market Information to assess and forecast the future workforce needs of the companies producing these emerging technologies is the first deliverable for the WE-BET project.

To accomplish this, an extensive literature review was conducted to identify and review economic and workforce articles and reports on the growing cell and gene therapy sector. Over 80 articles and reports were compiled and reviewed, providing a robust collection of the most current information on this topic. In addition, job postings data from Burning Glass Technologies¹ was collected and analyzed for each of the six regions designated in the WE-BET grant, to provide state and regional data related to the demand for these CGT technicians.

The job postings data presented in this report includes for each region: the numbers of job postings in 2020, the top employers, the top job titles, the top specialized and baseline skills in demand, the education and experience desired by employers and the job postings trend line for the past decade. In addition, the numbers of job postings for the first six months of 2021 is included to document the continuing growth trend.

The Six Regions and the College Leads

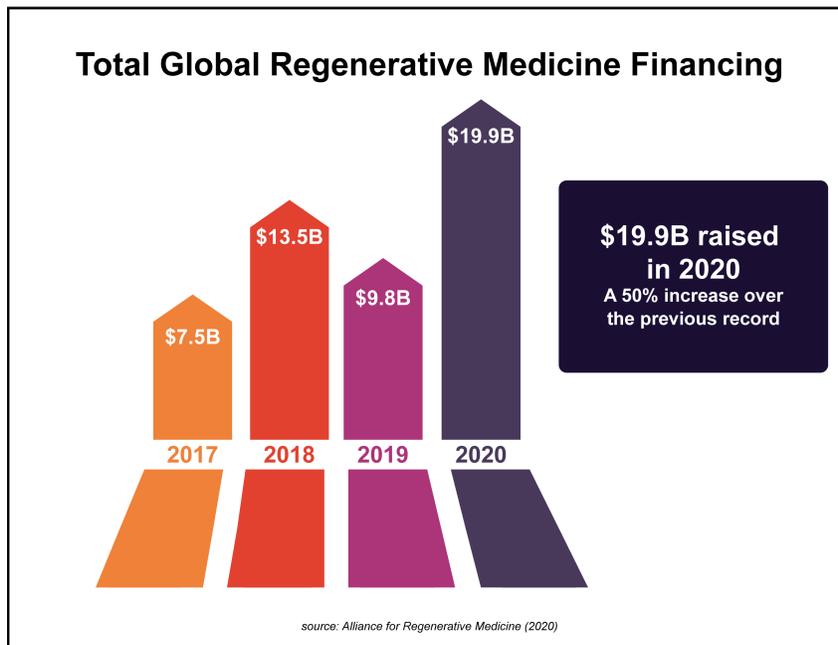
Six regions were selected based on evidence and the project team’s knowledge of where cell and gene therapy companies are located and thriving. The college partners in these regions were chosen for their geographic location and expertise. Each college is centrally located within a region that has a significant Biotechnology industry cluster. The involvement of colleges from different regions will enable the production of a national, harmonized curriculum. Each region and their college lead is listed below:

Region	College
San Francisco Bay region	Solano Community College (Vacaville, CA)
San Diego region	MiraCosta College (Oceanside, CA)
Seattle region	Shoreline College (Seattle, WA)
Philadelphia region	Montgomery County Community College (Blue Bell, PA)
Boston region	Quincy College (Quincy, MA)
North Carolina	Forsyth Technical Community College (Winston-Salem, NC)

¹ Burning Glass Technologies is a labor market analytics software company that uses artificial intelligence technology to analyze hundreds of millions of job postings to provide insight into labor market patterns.

Industry Overview: Growth and Economic Impact of the Cell and Gene Therapy Market

2020 was a pivotal year for regenerative medicine and advanced therapy financing and progress, with the pandemic revealing the importance of cell and gene therapies and genetic medicines more broadly. These innovative therapies are demonstrating profound, durable, and potentially curative therapeutic benefits for patients with a wide array of disorders — and investors have taken note. As shown in the following graphic, the sector raised nearly \$20 billion in 2020, shattering previous record of \$13.5B, set in 2018, despite the challenges posed by the COVID-19 pandemic.

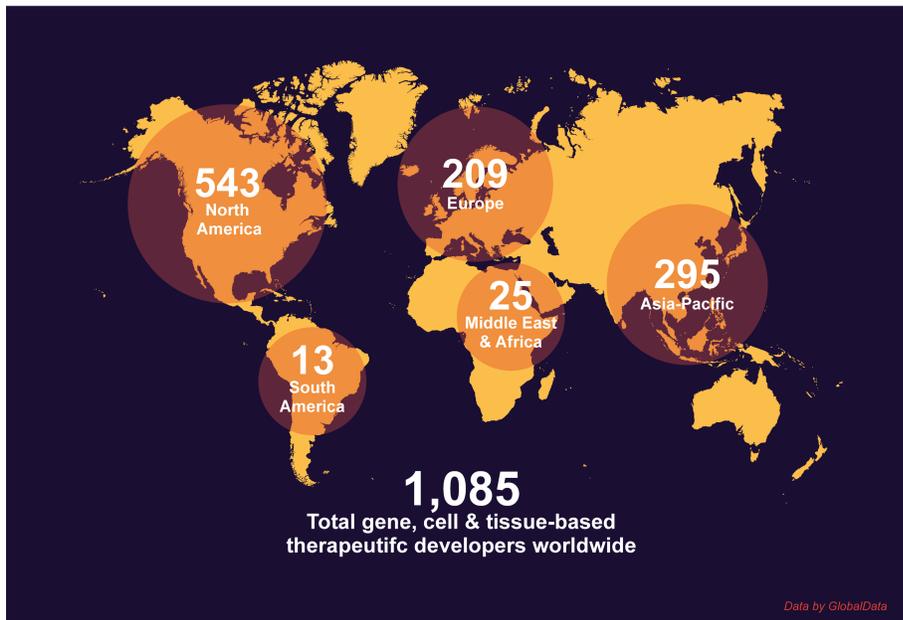


(Source: Alliance for Regenerative Medicine, 2020 Annual Report: Growth & Resilience in Regenerative Medicine)

In 2021, investor interest in *in vivo* gene therapy, gene editing, and cell-based therapies is expected to grow. Manufacturing and associated regulatory delays will continue as a gating factor due to the inevitable “growing pains” as academic work is translated to production at scale.

(Source: Alliance for Regenerative Medicine, 2020 Annual Report: Growth & Resilience in Regenerative Medicine)

In 2020, there were a total of 1,085 cell, gene, and tissue-based therapeutic developers worldwide, as depicted in the following graphic. North America had the largest number of therapeutic developers, with 543, followed by the Asia-Pacific region with 295. These two regions account for over 75% of total developers worldwide.



(Source: Alliance for Regenerative Medicine, 2020 Annual Report: Growth & Resilience in Regenerative Medicine)

Cell therapy, gene therapy, and gene editing comprise the next generation of life-enhancing and curative therapies. Briefly, they can be described as innovative approaches to medical research and practice in which cell or gene modifications are used to treat disease.

This sector has the potential to dramatically impact the life sciences industry, with much of the research and commercial activity within the cell and gene therapy sector having concentrated in the Philadelphia region over the last ten years. The first gene therapy approved for a genetic disease by the U.S. Food and Drug Administration (FDA) was developed by researchers at the University of Pennsylvania and the Children’s Hospital of Philadelphia (CHOP), while the first FDA-approved cell therapy was developed through collaboration between researchers at the University of Pennsylvania and Novartis.

However, the cell and gene therapy industry faces some challenges on a national and global scale:

- 1) As a relatively young field, the workforce is not strictly defined, and firms and academic researchers may struggle to find qualified talent with experience in the sector as well as knowledge of regulations, Good Manufacturing Practices (GMP), and commercialization.
- 2) Because startups in the U.S. are dependent upon product approval by the FDA, the industry is inherently risky, often with no defined career path and little job security for workers entering the startup world.

3) A shortage of manufacturing space for cell and gene therapy production is a universal barrier to scale. Currently, few companies manufacture therapies in-house.

(Source: Cell and Gene Therapy and Connected Health Workforce Analysis, ESI, 2020).

BIS Research recently reported that “the global gene therapy market was valued at \$1.07 billion in 2018 and is estimated to grow over \$8.95 billion by 2025.” The FDA anticipates that by 2020 it will be receiving up to 200 Investigational New Drug (IND) applications per year for cell- and gene-based therapies alone, another indication that manufacturing demands for this subsector of biopharma will be on the rise. *(Source: Window on the Workplace 2020: Workforce Training Needs for North Carolina’s Biopharma Manufacturing Industry)*

According to a recent CBRE report entitled “Markets Positioned for ‘Century of Biology’,” 2019 was a year of explosive growth for the biotech industry, fueled in part by the rapid emergence and proliferation of personalized medicine, **including the burgeoning cell and gene therapy industries.** The CBRE report calculates the life sciences sector is growing at its fastest pace since 2000, expanding 3.2% year-over-year. Over the next 10 years, some experts predict more than one-third of therapies will be cell- and gene- based. With anticipated faster FDA approvals and a potential tsunami of products coming to the market, companies will likely not be ready, unless they develop joint value creation with manufacturers and providers. *(Source: Deloitte Insights, 2020 global life sciences outlook)*

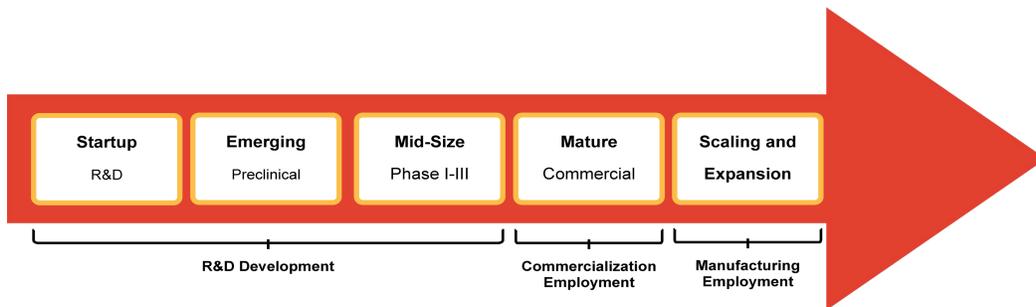
The Biomanufacturing Boom:

The successes in large molecule research associated with the shift toward more personalized medicine have spawned overwhelming demand for biomanufacturing space. This may usher in a period of rapid growth like that of high-quality laboratory space over the past several years. Demand for biomanufacturing space is particularly strong in **Boston-Cambridge, San Diego,** Washington, D.C.- Baltimore, **Raleigh-Durham** and New Jersey, where tenants are seeking about 3.5 million sq. ft. of space. *(Source: CBRE Report, October 2020).*

In 2020, manufacturing is expected to be a key differentiator for gene therapy companies. Contract manufacturing organizations (CMOs) and contract development and manufacturing organizations (CDMOs) are adding capacity. Big pharma companies are also building their own facilities and buying capacity from smaller companies. The following graphic shows that “Manufacturing Employment” occurs at the Scaling and Expansion stage of development, which is most likely when Cell and Gene

Therapy technicians would be hired.

Stages of Development for Cell and Gene Therapy Companies



(Source: Cell and Gene Therapy and Connected Health Workforce Analysis, ESI, 2020).

The demand for additional manufacturing capacity will likely be exacerbated by accelerated regulatory approvals. **By 2025, the Food and Drug Administration (FDA) expects it will be approving 10 to 20 cell and gene therapy products a year.** Phases of development are advancing so quickly that in order to be ready for commercialization, companies should be considering manufacturing at the beginning of development. **While the number of facilities are growing, experts say one of the biggest challenges will be staffing these facilities with enough trained and qualified personnel.**

(Source: Deloitte Insights, 2020 Global Life Sciences Outlook)



Biotechnology manufacturing students being trained at Montgomery County Community College in Blue Bell, PA

National Labor Market for the Cell and Gene Therapy Workforce

Workforce Overview

The biopharma industry has a significant workforce and economic footprint which is outlined below:

- Employed 1.87 million workers across more than 101,000 U.S. business establishments in 2018.
- Total economic impact on the U.S. economy totaled \$2.6 trillion dollars in 2018, as measured by overall output.
- Small and mid-sized biopharmaceutical companies comprised 71% of total biopharmaceutical industry employment and 99% of the business establishments.
- Smaller biopharmaceutical firms play a key role in innovation and have accounted for 60% or more of all FDA drug approvals each year over the past three years (2017-2019).
- As of mid-May 2020, there were more than 400 drug programs in development aimed at eradicating the COVID-19 disease, including 100 vaccine programs and 135 antiviral drug programs.

(Source: TEconomy/BIO 2020 Report)

California, North Carolina and Pennsylvania, three of the six regional hubs in the NIIMBL WE-BET project, together account for 28% of all employment in the Drugs and Pharmaceuticals sector in the country, as shown in the chart below.

States with Large and Specialized Employment in Drugs and Pharmaceuticals, 2018

State	Establishments 2018	Employment 2018	Location Quotient, 2018	Share of U.S. Employment
California	632	46,694	1.27	15.1%
New Jersey	304	21,950	2.57	7.1%
North Carolina	122	21,705	2.38	7.0%
Illinois	202	20,297	1.59	6.6%
Pennsylvania	138	18,064	1.41	5.9%
Indiana	69	17,093	2.61	5.5%

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

Workforce Challenges

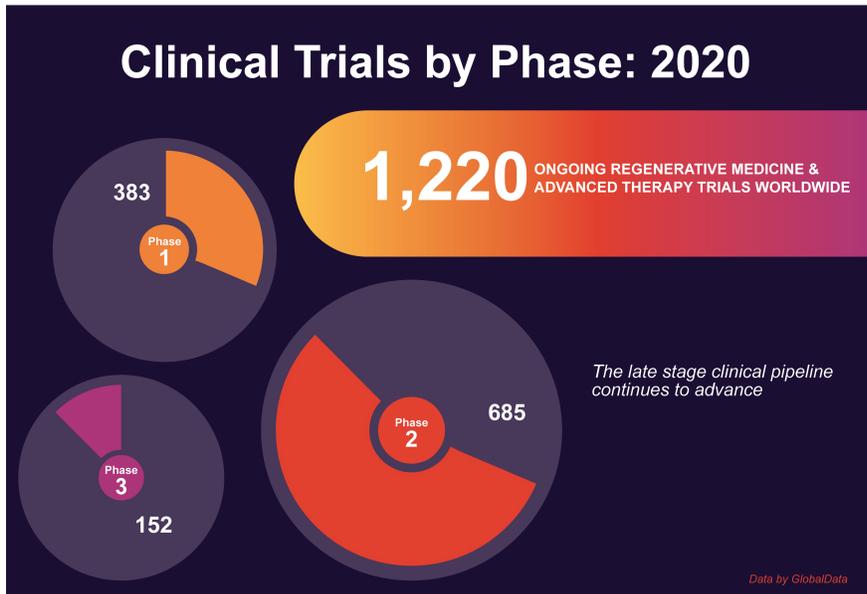
With all the economic success of the past few years for the bioscience industry, and the recent success and growth of the specialized cell and gene therapy sector, there is a gap between the demand for skilled cell and gene therapy workers and the available supply. This gap is creating a bottleneck that is slowing the abilities of innovative therapies to reach patients, delaying manufacturing scale-up and increasing learning and development costs. “The shortage runs across every functional team, at every level,” says Anshul Mangal, president, Project Farma & Precision ADVANCE. “What’s different about cell and gene therapy – versus biologics, for example – is the newness of the field. Cell and gene therapy is very personalized...very innovative. There’s great expertise in R&D, but few cell and gene therapies have reached commercial scale. Therefore, cell and gene therapies have fewer experienced personnel available with experience in scaling-up.”

“One of the largest gaps is in manufacturing,” Mangal said. Advanced therapies really started to become industrialized in the past five years and **talent in the manufacturing and technical operations spaces are in high demand. There’s not enough of people (with the right skills to fill the needs).”**

The U.S. leads the cell and gene therapy space, Mangal pointed out, so the need for manufacturing expertise here is great. “There are more than 1,000 cell and gene therapy developers in the world, and more than half of them are in the U.S. **Also, of the more than 1,200 advanced therapy clinical trials**

globally, most are in the U.S. (see graphic below). Close to \$20 billion was invested in cell and gene therapy last year.”

Regenerative Medicine and Advance Therapy Trials Worldwide (2020)



(Source: Alliance for Regenerative Medicine, 2020 Annual Report: Growth & Resilience in Regenerative Medicine)

“As of February 2020, however, the FDA has approved only nine cell and gene therapies treating cancer, eye diseases and rare hereditary diseases,” he said. “As these projects move towards commercial launches, manufacturing needs will be great. **The field is on the cusp of potentially explosive growth.** Currently, manufacturing professionals are being recruited from biologics and other disciplines, as companies hire people who leverage their previous experience and apply it to cell and gene therapy. **But it takes hundreds, if not thousands, of talented people to take each cell or gene therapy from clinical trials to commercial launch.**”

(Source: “Project Farma: Manufacturing Skills Gap Creates Bottleneck for Cell and Gene Therapy”, biospace.com, 2/19/21).

Growing Pains

Continued growth in the cell and gene therapy sector means that talent recruiting, acquisition and retention will remain a major challenge among companies competing for the skilled workforce required to fuel and sustain growth in the next decade. Listed below are six significant talent challenges that companies will face in 2020 and beyond as the industry continues to experience a biotech boom.

1. Poaching: Companies of all sizes will experience greater competition for regional talent which will increase the amount of poaching of employees from neighboring companies. The biggest issue with the increase of poaching is that it signals that new talent isn't being added to the market — it's just changing hands. The cluster doesn't actually grow, because new job openings aren't actually being filled, they are just shifting from one company to the next. Poaching is also a big factor that leads to many of the other challenges listed below.

2. Job Hopping: The frequency that employees change companies will also increase, which will reduce the time that skilled, experienced employees remain at a company, limiting the impact they can have. This type of environment not only costs companies more money but it stunts overall efficiencies that they can achieve because they are constantly recruiting, hiring and training for the same roles.

3. Compensation Inflation: The battle for talent will also drive up wages, bonuses and overall compensation package value as demand continues to grow, poaching increases and the supply continues to shrink. Hiring and retaining your employees will become much more costly as the bigger, better-funded companies inflate their compensations to win over the talent they need to grow and make it even harder for the smaller companies to succeed. One only has to look to Boston or the Bay Area to see how this dangerous cycle results in a higher cost of doing business that touches everything from rent prices and facility costs to company operating costs and the rollover into higher costs for the hundreds of products and services companies need to succeed.

4. Relocation: Increased competition for talent will force companies to recruit talent from other biotech clusters and be more open to remote and more decentralized work environments. Many companies have survived with a predominantly regional recruiting strategy and will have to rethink their hiring models. Many will also have to consider remote work opportunities for their employees. Clusters that can collectively articulate and market a more compelling story that showcases their region as an ideal location for relocation will be in a better position to attract talent.

5. Talent Development: The increased demand for talent combined with low unemployment, a growing skills gap, a retiring baby-boomer population and an industry growing on the foundation of rapidly evolving and novel technologies will cause almost every company to rethink its talent development strategy. Companies simply will not be able to meet their workforce requirements without better, more proactive, strategies for workforce development, training and re-deployment of existing employees.

6. Small Business Squeeze: As all of these factors begin to compound within a regional cluster, many businesses will have the financial resources and market position to respond and remain

competitive. However, many will not. Small, privately held biotech companies, contract labs, nonprofits and early-stage or slower-growth startups simply won't be able to attract the talent they need to survive. The weight of it all will cause many companies to eek along for a time until they are forced to seek a strategic acquisition or fold and go out of business. Since small businesses and startups are so crucial to an innovation economy, this can have a detrimental impact in the long run.

(Source: Hiring During a Biotech Boom: The Talent Challenges Facing Companies Across All Markets, Steven Surdez, BioBuzz.io, March 2020).

To say the cell and gene therapy sector is growing at a rapid pace is an understatement. The sector is projected to grow at an annual rate of more than 40 percent in the next 10 years alone. To put that in perspective: the human genome was only sequenced 16 years ago, in 2003. Since then, 729 gene therapies have been developed, and with the FDA recently announcing new policies to advance the development of safe and effective cell and gene therapies, more are sure to come.

There's a talent shortage in biotechnology today — and it's being felt across all sectors, not just within cell and gene therapy. For example, a 2018 survey of biotech employers conducted by the Massachusetts Biotechnology Educational Foundation found that for two-thirds of companies it took more than 10 weeks to fill many openings — about three times the national average. So the talent crisis for cell and gene therapy companies is part and parcel of a broader issue. But for biotech companies of all kinds, from industry leaders to startups, one question remains: **Where will they find the talent they need to support all of that growth?**

(Source: Solving the Talent Crisis in Gene Therapy, www.rlc.randstadusa.com, 2021)

Manufacturing Challenge

The rapid advancement of cell and gene therapy is creating challenges for manufacturers, many of which are high-growth and well-funded “gazelles” that lack the capacity to produce clinical trial batches or commercial scale medicines. While it would not be uncommon for such companies to utilize contract manufacturers (CMOs) to fulfill production needs, according to Bill Bullock, senior vice president, Economic Development of the North Carolina Biotechnology Center (NCBC), CMOs may not be a viable alternative for some young companies.

“The capacity at CMOs is expected to be very constrained in the near future,” says Bullock. “CMOs can handle only so many different products at each site, while still avoiding cross-contamination.” Thus, we can expect a surge in the construction of new cell production facilities in the next several years, both by

CMOs and private companies, who may wish to also maintain full control over their production operations. Because these facilities are relatively small (hundreds of liters of production, versus thousands or tens of thousands in a campaign-style biologics plant), to the uninitiated, site selection might seem like a relatively simple affair. However, the highly specialized manufacturing process imposes significant burdens due to the complexities associated with transporting, storing and processing raw materials (cell lines) and shipping finished product. The production of cell therapies, though not dissimilar to now-common biological medicine manufacturing, requires even greater vigilance against threats that can degrade purity, potency and efficacy.

(Source: Mining Talent in Cell and Gene Therapy Manufacturing, blsstrategies.com, 2019)

Cell and gene therapies demand advanced manufacturing techniques and procedures, requiring a higher level of skill and specialized knowledge than more conventional pharmaceutical operations. All biologics manufacturing occurs in a Good Manufacturing Practices (GMP) environment, an FDA quality/standards system that ensures consistency in the production process, from materials and premises, to equipment and training. Production of these therapies requires a labor force experienced in working in sterile environments, within highly documented processes requiring strict compliance and reporting obligations. The talent required to support the discovery-level work and clinical trials, regulatory approval, process development and technology transfer typically has a Masters degree or specialized Ph.D. level of education.

However, the production process requires a large compliment of well-trained manufacturing associates. These employees, **which typically constitute more than half to two-thirds of the overall staffing requirements for production facilities**, primarily have four-year (plus) degrees, **although some companies hire experienced biologics technicians with only two-year degrees**. These production-oriented positions are generally sourced in the local market, such that availability of workers and the number of trainees coming through specialized training programs offered by workforce development institutions become an important site selection criterion in comparing regions for such projects.

The most effective communities are those with community colleges and other workforce development institutions that are getting ahead of growing talent demand by working with companies and industry groups to design curricular and training materials around the job descriptions for these positions, assuring companies of a reliable future supply of competent recruits as well as job opportunities for residents of the region. *(Source: The Rise of Gene & Cell Therapy and The Resulting*

Need For In-House Production Facilities: A Guide; Jay Biggins, Executive Managing Director, Biggins Lacy Shapiro & Co.; 2020)

Talent: Critical Success Factor

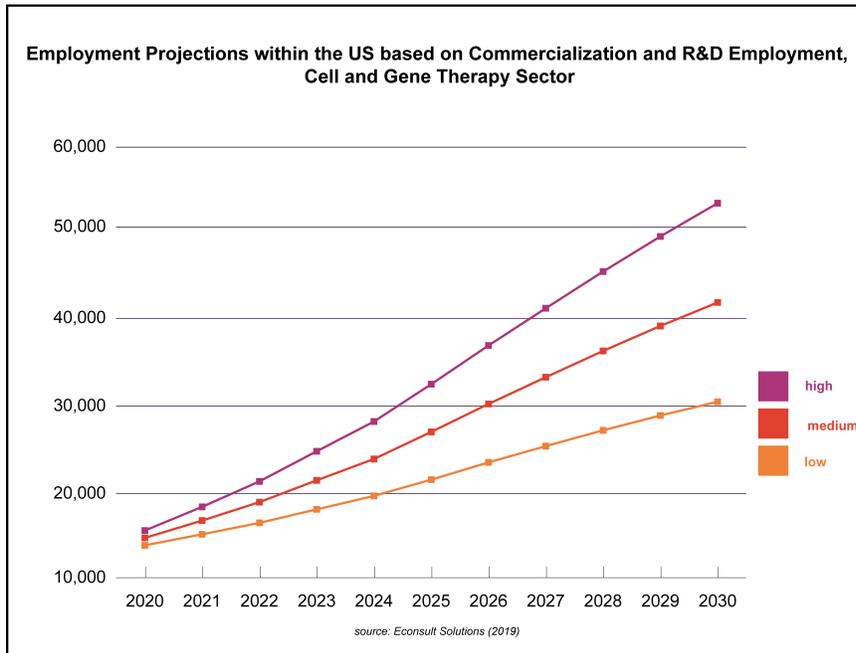
Because of the constant innovation occurring in this industry, the overriding criterion during site selection for cell manufacture will almost always be the availability of technical talent. Key manufacturing functions and talent needs include cGMP production (“cGMP” refers to Current Good Manufacturing Practice regulations enforced by the U.S. FDA); quality assurance and quality control; logistics; skilled maintenance; and process validation (designing a manufacturing process capable of meeting FDA-enforced standards). Requirements for these positions will run the gamut from two years of technical/vocational education through doctorate-level degrees. Almost all entail some prior exposure to the clean-room manufacturing of biologics, and more specifically, cell therapeutics.

Because this nascent industry’s need for talent can outweigh concerns about costs, some cell therapy companies are opting to build their first manufacturing facilities in established, but expensive, biotech hubs. For example, Allogene Therapeutics, a company with a promising cell therapy treatment for cancer, recently announced plans to build a manufacturing facility in the San Francisco Bay Area. Allogene, who has used CMOs in the past, also cited the need to bring the manufacturing “in-house” in order to keep pace with the rapidly changing innovations in the cell manufacturing process.

(Source: Mining Talent in Cell and Gene Therapy Manufacturing, blsstrategies.com, 2019)

Projections for National Employment Growth

An employment growth estimate – high, medium and low growth - for the United States over the next ten years (2020-2030), is depicted in the following chart.



(Source: *Cell and Gene Therapy and Connected Health Workforce Analysis*, ESI, 2020).

A Promising Talent Development Model from the UK

Research from the U.K.'s **Cell and Gene Therapy Catapult** (CGTC) noted that the U.K.'s workforce in this space needed to double from 3,000 in 2019 to 6,000 by 2024. Comparable data for the U.S. is lacking. In the U.K., the CGTC launched the **Advanced Therapies Skills Training Network** to offer online training, national training centers and a career converter tool. The career converter helps users measure their skills against those needed in the advanced therapies and vaccine manufacturing areas. Many skills are transferrable, including project management, digital expertise and business and technical acumen.

The CGTC also is working with the British government and Innovate U.K. to coordinate training courses and increase the number of training centers throughout the country. In 2018, it created **apprenticeships** with 37 companies to bring workers into the industry. So far, 137 apprentices have signed up – 2.7 times more than anticipated.

(Source: “*Project Farma: Manufacturing Skills Gap Creates Bottleneck for Cell and Gene Therapy*”, *biospace.com*, 2/19/21).



A biotechnology manufacturing student at Solano Community College in Vacaville, CA

The Six Regions

The next section of this labor market report will provide the following information for each of the six regions participating in the WE-BET project:

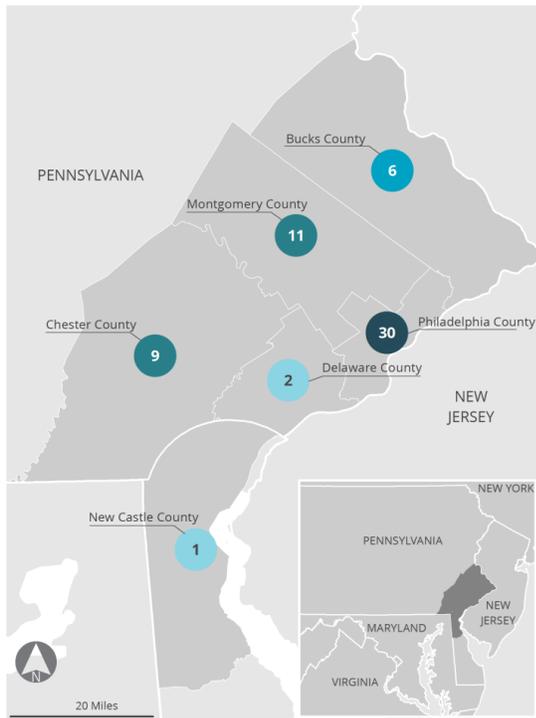
- 1) The growth and economic impact of the cell and gene therapy sector in the region.
- 2) The labor market for the cell and gene therapy workforce in the region.

Philadelphia Region

Growth and Economic Impact of Cell and Gene Therapy Companies

Over the last twenty years, the cell and gene therapy and connected health sectors have flourished in Greater Philadelphia. A leader in cell and gene therapy innovation, the region has supported the expansion of this sector through its collaborative relationships among top-tier academic institutions, medical centers, and commercial enterprises. *(Source: Cell and Gene Therapy and Connected Health Workforce Analysis, ESI, 2020).*

Figure 3.1: Cell and gene therapies companies, CMOs, and universities/hospitals in Greater Philadelphia



Source: ArcMap (2019) and Econsult Solutions (2019)

Firms in cell and gene therapy are predominantly located in University City and the Navy Yard, with some firms of significant size in suburban Philadelphia. University City, in particular, benefits from a concentration of research organizations, universities, and hospitals, including the University of Pennsylvania, Penn Medicine, Drexel University, The Wistar Institute, the University of the Sciences, and Children’s Hospital of Philadelphia (CHOP).

For research specifically related to cell and gene therapy, researchers have been awarded more than \$240 million in NIH funding in the last five years. Funding for cell and gene therapy in the Philadelphia region has grown 36% over the past five years. During 2018-19, there was roughly \$800 million in venture capital invested in cell and gene therapy companies in the region. (Source: *Cell and Gene Therapy and Connected Health Workforce Analysis, ESI, 2020*).

75% of the known vectors used in cell and immune-therapy research around the world were identified at the University of Pennsylvania. Philadelphia also is home to the first in-vivo gene therapy manufacturing. More than \$550 million has already been invested in advanced cell and gene therapy manufacturing in the region. (Source: *Cell & Gene.com; 2019*).

Greater Philadelphia ranked #7 in Top 10 U.S. Biopharma Clusters in 2020

As of 2020, Greater Philadelphia was home to 36 cell and gene therapy (CGT) companies, pioneering researchers, and a workforce of approximately 4,900 employees. CGT growth helps explain why the region has more than 1 million square feet of new lab space under construction. Companies such as WuXi Apptec, Iovance, and Adaptimmune have in recent years set up facilities at the Navy Yard district in South Philadelphia and there has been recent expansion at the University City Science Center and a new 50,000 SF biotech incubator is planned for the Schuylkill Yards Innovation District.

(Source: "Brandywine Realty Trust and Pennsylvania Biotechnology Center Partner on Life Science Incubator within 14-acre \$3.5 billion Schuylkill Yards Innovation Neighborhood", www.businesswire.com, 2021).

Counties neighboring Philadelphia are also showing expansion in the biotechnology CGT space. MRA Group is bringing the 600,000-square-foot [Spring House Innovation](#) Park to life in Lower Gwynedd Township, Montgomery County, while in Doylestown, Bucks County, the [Pennsylvania Biotechnology Center](#) is constructing a \$19 million, 15,000-square-foot lab building.

In addition, the Center for Breakthrough Medicines (CBM) has signed a long-term lease for 680,000 square feet at The Discovery Labs in King of Prussia. The new facility will relieve the cell and gene therapy industry's production constraints, and will employ up to 2,000 workers, including scientists, manufacturing experts, lab technicians and support staff. (Source: Cell & Gene.com; 2020). [The Center for Breakthrough Medicines](#) is an innovative cell and gene therapy-focused contract development and manufacturing organization located in the heart of "Cellicon Valley". CBM's integrated and comprehensive service offering provides a one-source solution to accelerate speed to market for advanced therapies. A client-driven approach coupled with a patient-centric culture delivers high-quality and reliable process and analytical development, **viral vector manufacturing, GMP testing, cell therapy bioprocessing, plasmid production, and cell banking services** for a full product's life cycle.

(Source: Why Philadelphia is Poised to Become a Top Cell and Gene Therapy Cluster, biobuzz.io, 2021)

Greater Philadelphia ranks fifth in lab space (with 23.37 million square feet), and Venture Capital (with \$1.6 billion going to CGT companies). The region places sixth in patents (5,148), and eighth in both NIH funding (2,991 awards totaling \$1.48 billion), and jobs (69,500 according to Select Greater Philadelphia).

(Source: "Top 10 U.S. Biopharma Clusters", genengnews.com, 2020)

Labor Market for Cell and Gene Therapy Workforce

The following workforce section will be organized in two parts: 1) findings from a “literature review” of existing workforce research, reports and articles documenting the demand for biomanufacturing technicians with cell and gene therapy (CGT) knowledge and skills and 2) findings from job postings data related to the demand for CGT technicians which will include data on numbers of job postings, top employers, top job titles, skills in demand, and education and experience desired by employers.

Philadelphia Region Life Sciences Employment

In 2018, there were 14,370 jobs in pharmaceutical manufacturing in the Philadelphia region. Although not all of these jobs are in cell or gene therapy development, the pharmaceutical manufacturing sector provides a sense of the potential talent pool for cell and gene therapy firms. (*Source: Bureau of Labor Statistics*).

A research firm, Econosult Solutions, surveyed 35 cell and gene therapy companies in the Philadelphia region in 2019 and asked what level of growth they anticipated in the region in the next three to five years. The majority of respondents (71 percent) anticipated medium growth, defined as 25 percent to 74 percent growth. Twenty percent of respondents anticipated large growth, defined as 75 percent growth or greater. (*Source: “2020 Cell and Gene Therapy and Connected Health Talent Needs Assessment, Econosult Solutions, Inc.; 2019*).

When asked to rank the largest barriers to growth in the cell and gene therapy sector in the Philadelphia region, respondents identified funding and skilled workforce as two of the largest. Of 27 respondents, 74 percent identified *funding* as either the first or second largest barrier to growth, **while 70 percent identified *skilled workforce* as the first or second largest barrier to growth.** (*Source: Econosult Solutions, Inc.; 2019*).

Philadelphia Cell and Gene Therapy Companies

Company	Current Jobs	Projected Growth
Spark Therapeutics	450+	
Adaptimmune	150	Built a facility in 2015 for manufacturing cell and gene therapies and plan to start a clinical trial in 2022
Tmunity Therapeutics	60	
Century Therapeutics	60+	
Castle Creek Biosciences	40	currently conducting a clinical trial
Passage Bio	30	
Carisma Therapeutics	30	plans to initiate a clinical trial
Cabeletta Bio	22	expects to start a clinical trial in 2020
Imvax	12	
Total	844+	

(Source: "9 Philly Companies on the Cutting Edge of Cell and Gene Therapy Innovation", Philadelphia Magazine, May 2020).

Philadelphia's Talent Pipeline Collaborative

Industry leaders in the Philadelphia region have created the Life Science Talent Pipeline Collaborative to ensure a strong talent pool for the future. The Greater Philadelphia cell and gene therapy hub already is home to 36 cell and gene therapy R&D companies, and expectations are for rapid job growth as those companies continue to develop, new companies are born, and others relocate to or expand in the region. The Collaborative will address the talent needs on the horizon, including attracting and retaining talent.

The newly formed Collaborative is employer-led, with actions guided by employers and for employers. The Chamber of Commerce for Greater Philadelphia serves as convener of the group. So far the Collaborative includes 16 organizations representing cell and gene therapies companies and specific academic research labs in the cell and gene therapy space, with even more participants expected to join the group over the coming months. The members include: Adaptimmune; AmerisourceBergen; Amicus Therapeutics; Cabaletta Bio; Carisma Therapeutics Inc.; Children's Hospital of Philadelphia; Integral Molecular; Iovance Biotherapeutics Inc.; Johnson & Johnson; Merck & Company, Inc.; Passage Bio;

Rockland Immunochemicals; Spark Therapeutics, Inc.; Spirovant; University of Pennsylvania; and WuXi Advanced Therapies.

Data from the “2020 Cell and Gene Therapy and Connected Health Talent Needs Assessment” guides the work. The independent study, which was conducted by Econsult Solutions, Inc. (ESI), an economic consulting firm, analyzed the current workforce landscape in the region and assessed future talent needs. As the study states, in 2019, there were approximately 4,900 employees working in the Greater Philadelphia region at cell and gene therapy companies, CMOS, biopharma companies, research organizations or research hospitals in the cell and gene therapy fields.

ESI estimated that, using mid-range growth estimates, in the next 10 years the workforce could grow between 35 percent and 94 percent. That could account for as many as 4,500 new jobs over the period, bringing the total cell and gene therapy sector jobs in the region to 9,400. Using high-range growth estimates, the job growth could be as much as 54 percent to 136 percent, which could add as many as 6,600 new jobs over the period, bringing the region’s total number of employees in the cell and gene therapy field to as high as 11,500 employees.

(Source: “Philadelphia’s Talent Pipeline Collaborative Readies Region for Cell and Gene Therapy Job Growth”; Claire Greenwood, Executive Director, Chamber of Commerce for Greater Philadelphia’s regional CEO Council for Growth and Patricia Day, Manager, Leadership Engagement, Chamber of Commerce for Greater Philadelphia; cellandgene.com, February 2021).

Audrey Greenberg, Co-Founder and Executive Director of [The Discovery Labs](#) in Philadelphia, touted the advantages that companies found in the ecosystem known as “*Cellicon Valley*”, and predicted the city could become one of the most important hubs for the biopharma industry in the world. In addition to its reputation for delivering cell and [gene therapy innovation](#), there are other key elements that will contribute to the region’s rise in the life science hub rankings. First, Greenberg pointed to the available talent pool in the greater Philadelphia region. **She said there are more than 70,000 life sciences employees and nearly 10,000 with [specific expertise in cell and gene therapy](#).** The region’s rich concentration of colleges and universities also churn out new next-generation talent annually.

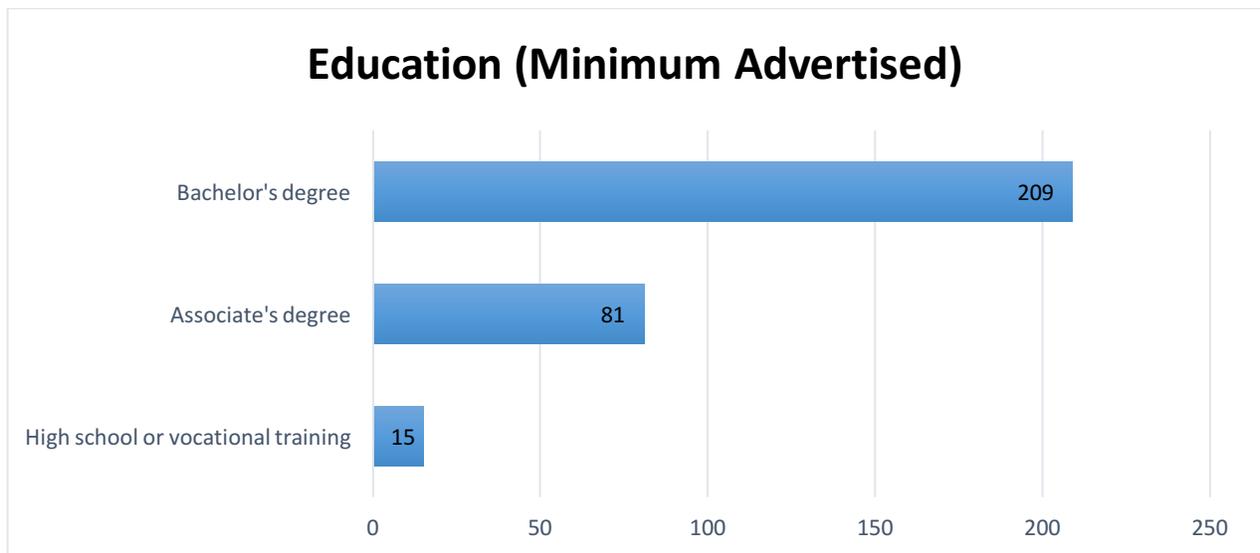
(Source: “Why Philadelphia is Poised to Become a Top Cell and Gene Therapy Cluster”, biobuzz.io, 2021)

Findings from 2020 Job Postings Data in Philadelphia/Pennsylvania Region

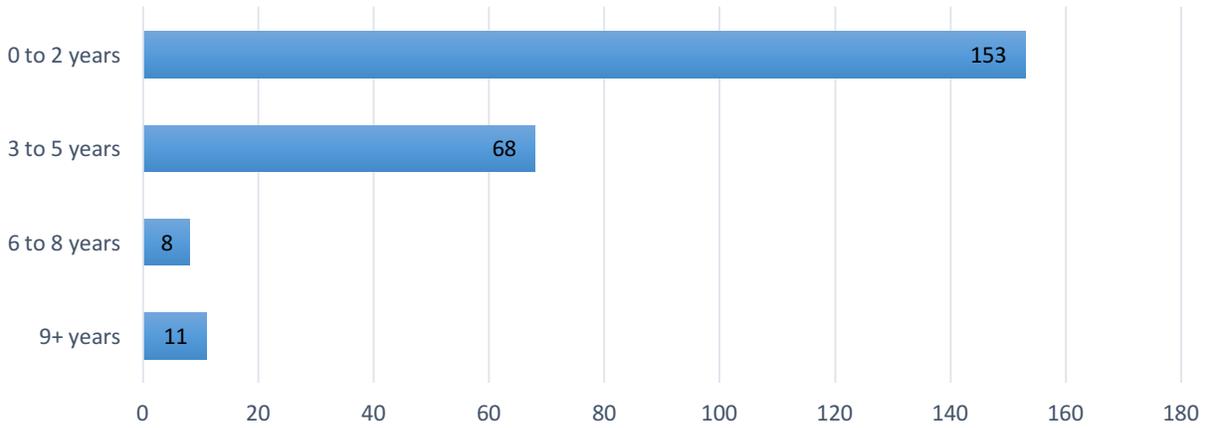
The following section displays job postings data related to demand for cell and gene therapy technicians in Pennsylvania for calendar year 2020. **There were 322 job postings in the Philadelphia/Pennsylvania region in 2020** from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles.

The data in the following charts is from Burning Glass/Labor Insight and covers the following information:

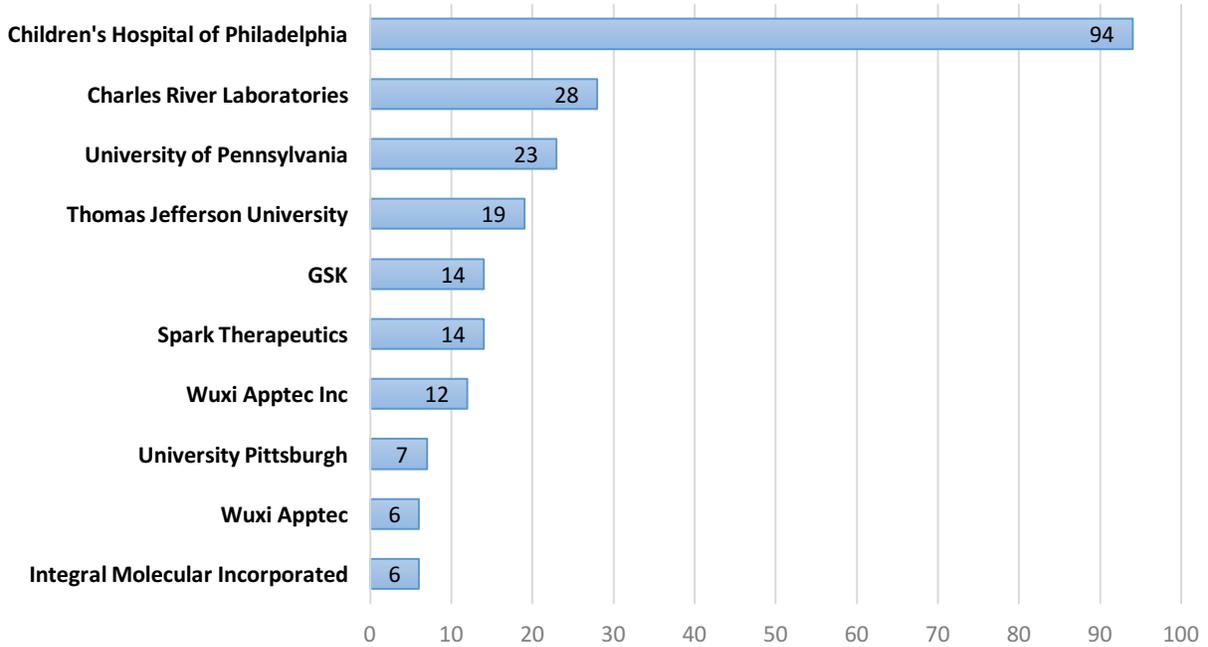
- Education level and experience employers are seeking
- Top employers in the state with most job postings
- Top job titles posted by cell and gene-therapy companies
- Top specialized skills and baseline/workplace skills most in demand by employers
- Trend line for these positions by region looking back 10 years



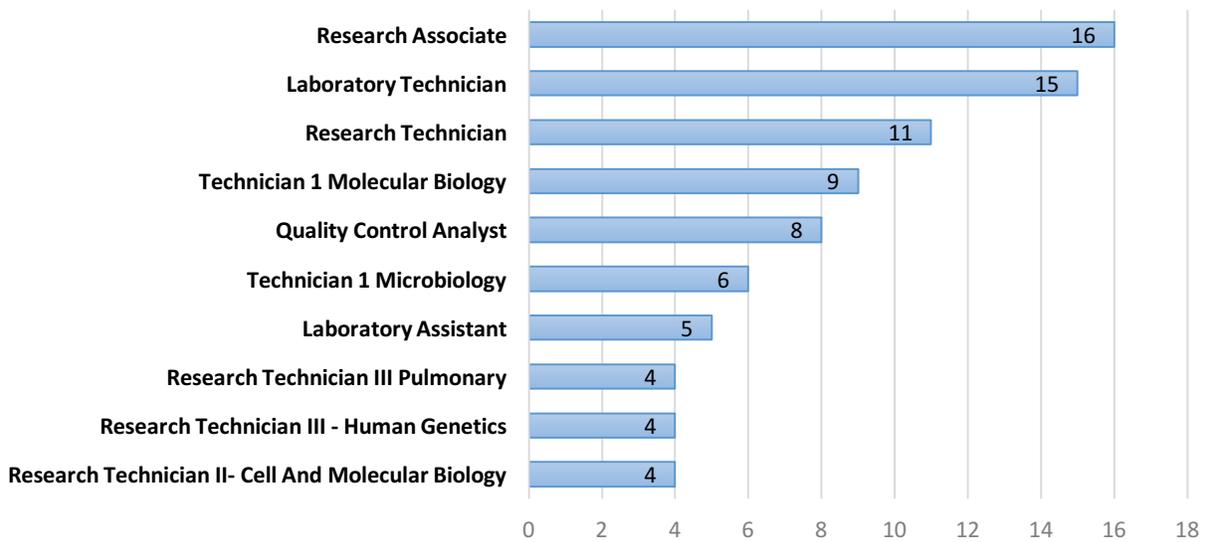
Experience Requirements for a Skill or Credential



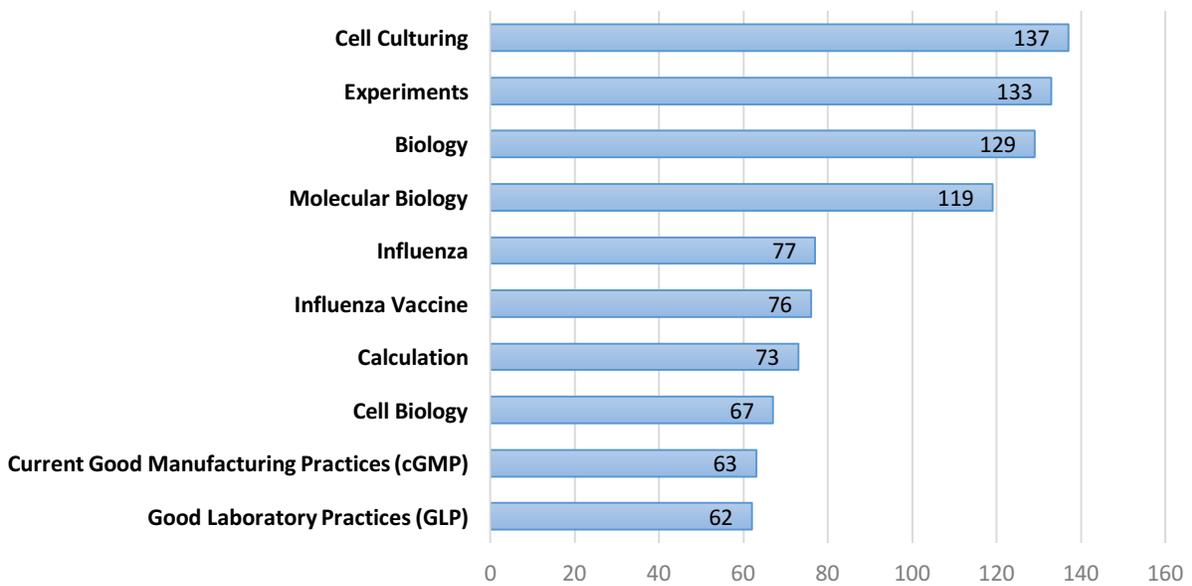
Top Employers

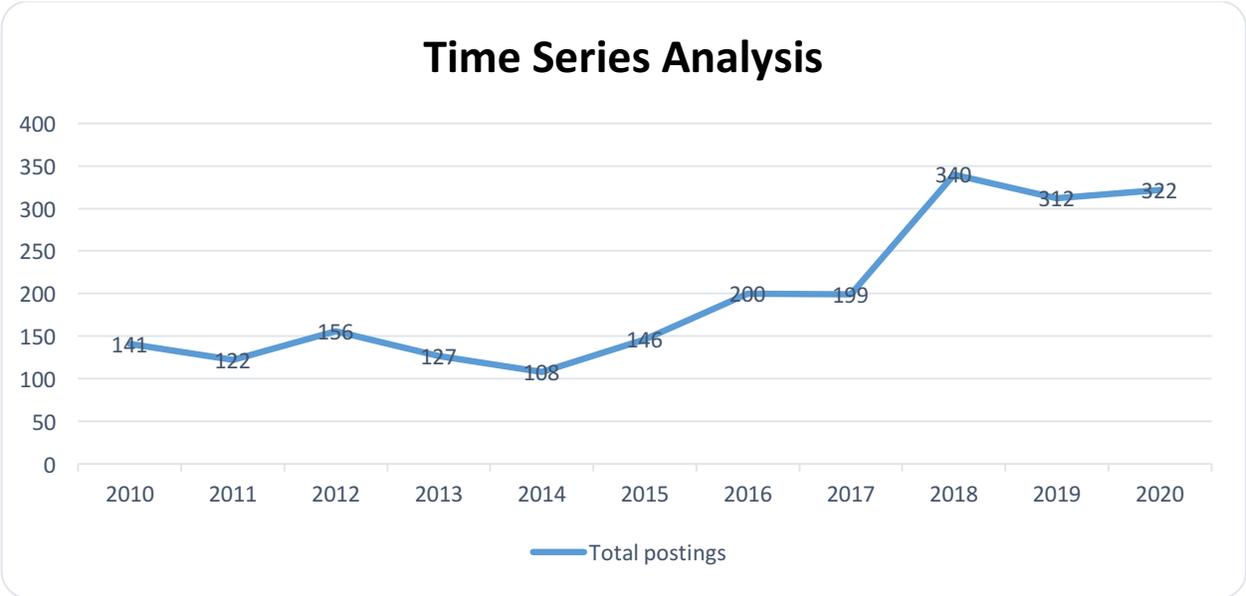
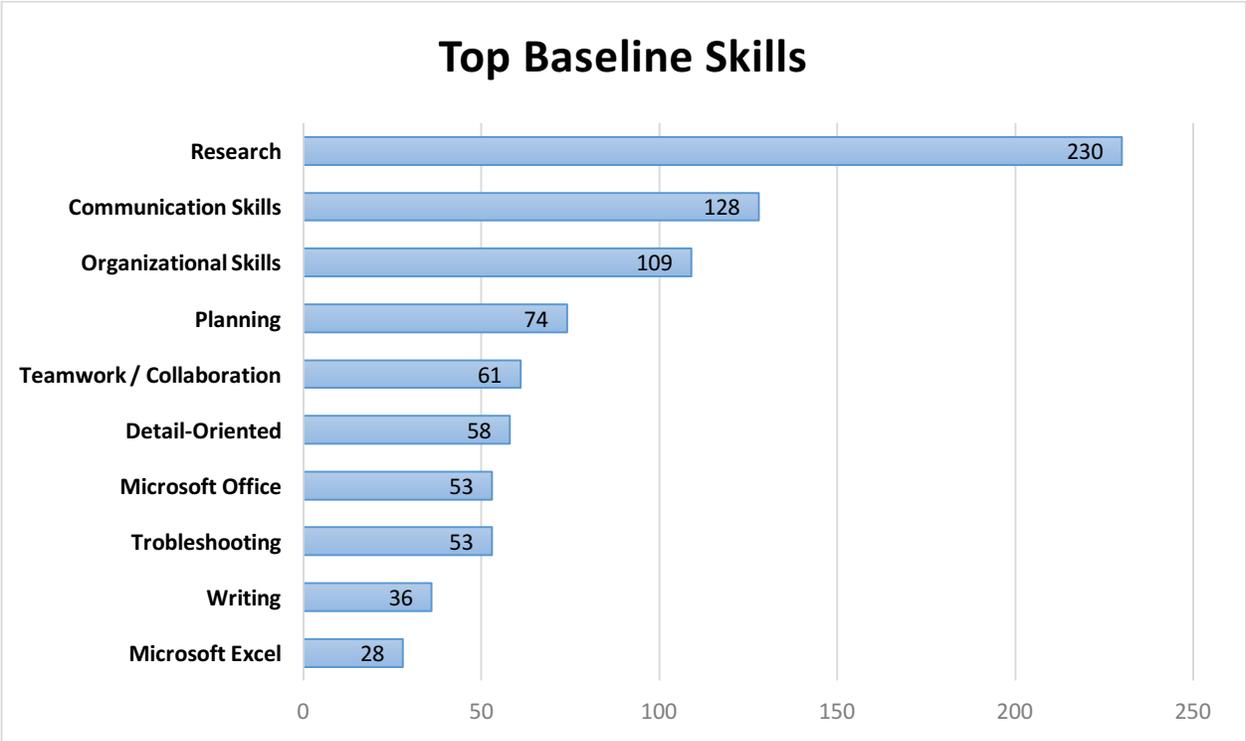


Top Job Titles



Top Specialized Skills





Job Postings for January - June 2021

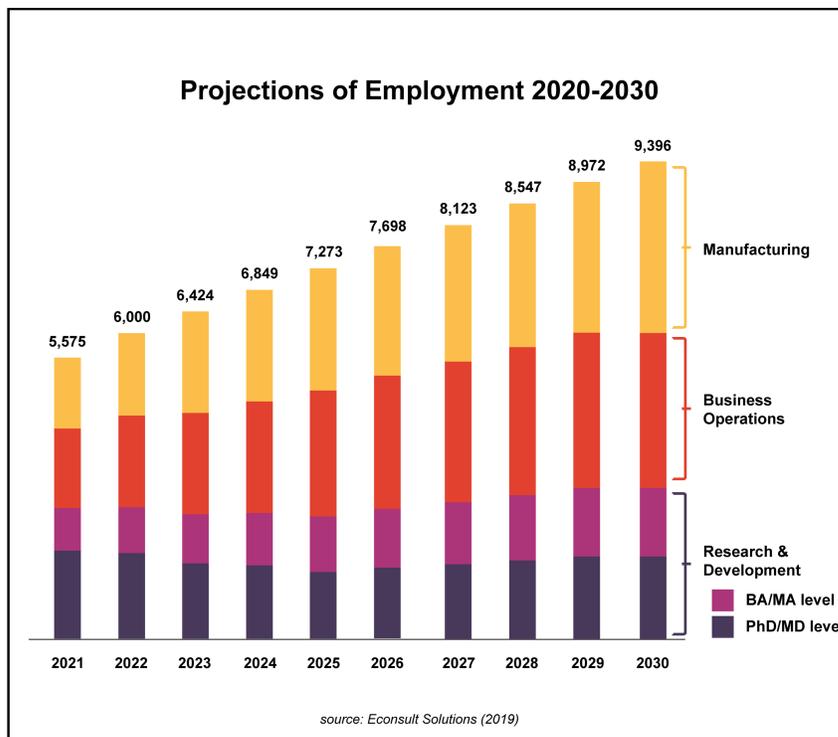
For the Philadelphia/Pennsylvania region, the first six months of 2021 showed strong job posting activity from cell and gene therapy (CGT) companies. During the period, there were 206 job postings from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles. If the trend for the first six months continued through the second half of the year, then the projected

annualized number for the region would be 412 job postings, **which would be a 28% increase** compared to the 322 job postings in 2020.

Projections for Future Job Growth

The following chart shows employment projections for the CGT workforce in the Philadelphia region from 2020 -2030 by type of employee – Manufacturing, Business Operations and Research and Development. The projected growth in employment over the ten-year period is a robust 69%, or an average annual growth rate of just under 7% per year.

Philadelphia Employment Projections – 2020-2030



(Source: “2020 Cell and Gene Therapy and Connected Health Talent Needs Assessment, Econsult Solutions, Inc.; 2019)

North Carolina Region

Growth and Economic Impact of Cell and Gene Therapy Companies

According to the annual year-end analysis by the North Carolina Biotechnology Center’s Life Science Intelligence team, **30,181 people were employed in life sciences production and manufacturing**

companies at year-end 2020. They make an expanding array of products, including small-molecule pharmaceuticals, monoclonal antibodies, industrial enzymes, vaccines, and cell- and gene-based therapies. **About 37,000 additional life sciences workers statewide work in research and development or contract research and testing.**

The overall life science sector has grown in North Carolina from 131 companies in 1997 to more than 775 companies in 2020. Currently, the overall economic impact of the life sciences on the state’s economy includes:

- 67,000 direct employees
- \$16.7 billion in wages and benefits
- \$84 billion in economic output
- \$2.2 billion in state and local taxes

Gene therapy has become an increasingly important subset of the biologics market, especially in North Carolina. Biopharma manufacturing is expanding as novel technologies including cell and gene therapies have moved from research laboratories to commercial manufacturing. For example, Pfizer’s 2016 acquisition of Bamboo Therapeutics prompted an expansion of Pfizer’s Sanford, North Carolina facility to accommodate gene therapy manufacturing. *(Sources: Window on the Workplace 2020: Workforce Training Needs for North Carolina’s Biopharma Manufacturing Industry and North Carolina Biotechnology Center).*

The timeline below shows the rapid development of cell and gene therapies and the growth of key companies in the region, since 2015.

Growth of BioPharma Manufacturing in North Carolina – 2015-2020

Year	Events
2015	StrideBio founded (Duke) Locus Biosciences founded (NC State) CRISPR successfully used to improve muscle function in mouse model of DMD (Duke & UNC-CH) Dr. Steven Gray pioneers first gene delivery approach into spinal fluid for neuro disorder (UNC-CH)
2016	Pfizer acquires UNC-CH startup Bamboo Therapeutics
2017	Pfizer adds gene therapy production capabilities to its Sanford site bluebird bio announces establishment of new lentiviral vector manufacturing facility in Durham
2018	AveXis announces new AAV gene therapy manufacturing site in Durham
2019	AveXis expands to double footprint in Durham with \$115 million manufacturing site, adding 200 jobs

	<p>Cellctis announces establishment of a commercial-scale cell therapy manufacturing facility in Raleigh</p> <p>Precision BioSciences opens first in-house cGMP manufacturing facility dedicated to genome-edited allogeneic CAR T therapy in the US</p> <p>FDA Approval of AveXis' Zolgensma</p> <p>Pfizer announces \$500 million expansion of its Sanford site for commercial gene therapy manufacturing, adding 300 jobs to the site's 650 employees</p>
2020	<p>Eli Lilly plans to build a \$474 million pharma manufacturing plant in RTP, creating 462 new jobs.</p> <p>bluebird bio opened its first wholly owned manufacturing facility in Durham, where it produces lentiviral vector for the company's investigational gene and cell therapies</p> <p>Merck & Co. announces a \$680 million, 425 job expansion, that will include building a 225,000-sq. ft. addition to its Maurice R. Hilleman Center for Vaccine Manufacturing in Durham</p> <p>Biogen announces a \$200 million gene therapy manufacturing facility at RTP, set to add 90 jobs to the company's 1,900-person workforce</p>

(Sources: Window on the Workplace 2020: Workforce Training Needs for North Carolina's Biopharma Manufacturing Industry; "In Praise of Lesser-Sung Life Sciences Clusters", www.genengnews.com, 6/25/20; "Top 10 U.S. Biopharma Clusters", Genetic Engineering & Biotechnology News, www.genengnews.com, 2019,2020).

Raleigh-Durham, NC (includes Research Triangle Park) Ranked #7 in Top 10 U.S. Biopharma Clusters in 2019 and Ranked #9 in 2020.

Raleigh-Durham-RTP ranks 10th in patents (1,281), seventh in both VC funding (\$726 million in 14 deals) and lab space (14.7 million square feet), fifth in NIH funding (2,145 awards totaling nearly \$1.15 billion) and currently ranks 10th in jobs with 36,507 jobs, though the state-funded North Carolina Biotechnology Center counts more than 63,000 jobs statewide). *(Source: "Top 10 U.S. Biopharma Clusters", Genetic Engineering & Biotechnology News, www.genengnews.com, 2019).*

In 2020, Raleigh-Durham-RTP-Chapel Hill ranked fifth in NIH funding (2,803 awards totaling \$2.308 billion), eighth in lab space (11.4 million square feet). The region ranked 10th in patents (1,408), venture capital (approximately \$772 million, according to the state-funded North Carolina Biotechnology Center)—and jobs (39,588, though the North Carolina Biotechnology Center tallies more than 67,000 statewide).

(Source: "Top 10 U.S. Biopharma Clusters", Genetic Engineering & Biotechnology News, www.genengnews.com, 2020)

Research Triangle Park Maintains Low Biomanufacturing Costs

The North Carolina region encompasses Raleigh, Durham, and Chapel Hill, each of which contributes elements to Research Triangle Park (RTP). The region offers the lowest operating biomanufacturing

costs of any U.S. biopharma location at \$37.2 million per year, according to a recently published analysis from John Boyd, CEO of the Boyd Company, a site selection advisory company in Princeton, NJ.

For more than a generation, the region has attracted the manufacturing operations of pharma giants eager to tap into the region's innovation while reducing costs over Northeast locations. More recently, Raleigh–Durham–Chapel Hill/RTP has enjoyed a series of completed and announced expansions by biopharma companies. The region accounts for over 60% (40,000) of North Carolina's more than 66,000 life sciences employees, and over 70% (525) of the state's 735 life sciences companies, says Jim Shamp, a spokesperson for the state-funded North Carolina Biotechnology Center.

A Biotech Center grant in 1993 enabled the recruitment to the University of North Carolina at Chapel Hill of R. Jude Samulski, Ph.D., who led the university's Gene Therapy Center for 25 years and still heads a research laboratory there. He established global leadership in commercializing the use of the AAV as a vector in delivering gene therapy as a co-founder of Asklepios BioPharmaceutical (AskBio). Samulski was also scientific founder of an AskBio spinout, Bamboo Therapeutics of Chapel Hill, and served as its chief scientific officer and executive chairman until it was acquired by Pfizer in 2016 for \$645 million.

(Source: "In Praise of Lesser-Sung Life Sciences Clusters", www.genengnews.com, 6/25/20).

Life sciences companies from around the state, nation and world are expanding their capacity to manufacture pharmaceuticals and biological therapies in North Carolina. Expansions announced in 2020 will bring more than \$2.3 billion in investment **and over 2,800 new jobs in biopharma manufacturing to the state in coming months and years**. Ten companies will first create construction-related jobs and then bioscience jobs as they build and operationalize new or expanded plants in communities including Clayton, Durham, Greenville, Maxton, Research Triangle Park and Sanford. **Here are the major life sciences manufacturing projects announced in 2020:**

- Global pharmaceutical giant [Eli Lilly and Company](#) announced plans to build its first North Carolina manufacturing facility in Research Triangle Park, investing \$474 million and creating 462 new jobs. Lilly officials said they chose North Carolina over competing sites in Indianapolis and Philadelphia, primarily because of the state's workforce capabilities.
- [Audentes Therapeutics](#), a San Francisco gene therapy company that was purchased in January 2020 by Tokyo-based [Astellas Pharma](#), announced it would establish a \$109.4 million, 209-employee gene therapy production facility in Sanford. The company chose to join North Carolina's burgeoning gene

therapy ecosystem after also considering its home state of California, as well as Massachusetts and Colorado.

- [Grifols](#), a global biotherapeutics company with more than 2,000 employees in North Carolina, announced it would add 300 more to its Clayton workforce as part of a \$351.6 million expansion of its blood plasma operations there. The project is the latest of several expansions that are making the Clayton site one of the world's largest manufacturing plants for plasma-derived medicines.
- A young Boston-area gene therapy company, [Beam Therapeutics](#), announced plans to build an \$83 million biomanufacturing facility in Durham. The 200,000-square-foot facility could employ more than 200 people over five years.
- [Merck's](#) Maurice R. Hilleman Center for Vaccine Manufacturing in Durham disclosed plans to hire 100 more employees over the next few years as it builds a new facility to increase production of a bladder cancer drug.
- Connecticut-based [ApiJect Systems](#) announced construction of a "gigafactory" on a 185-acre site in RTP at a potential cost of \$785 million and adding up to 650 jobs. ApiJect, which makes an experimental disposable injection device, said the 1-million-square-foot campus will be capable of producing 3 billion single-dose prefilled injectors annually.
- [KBI Biopharma](#), a contract drug development and manufacturing company with operations in Durham, announced a new manufacturing facility near Research Triangle Park that will employ more than 200 people in operations and quality assurance. KBI will co-invest \$150 million in the 140,000-square-foot facility in collaboration with an undisclosed pharmaceutical client to support manufacturing of the client's therapeutic proteins.
- [Huvepharma](#), a global pharmaceutical company that develops and manufactures human- and animal-health products, announced a \$1.9 million expansion of its poultry vaccines plant in Maxton, in rural Scotland County, that will add 10 jobs.
- [Thermo Fisher Scientific](#), a global life sciences services company with major operations in North Carolina, unveiled plans to add 500 new jobs in Greenville over the next two years in a \$500 million expansion of its sterile drug product development and commercial manufacturing of critical medicines, therapies and vaccines.

- Dallas-based [Taysha Gene Therapies](#) announced plans to invest \$75 million in a 150,000-square-foot gene therapy manufacturing facility in Durham County that will employ more than 200 people by the end of 2023.

The momentum of 2020 expansions continued as three additional companies announced projects in early 2021:

- California gene therapy innovator [Adverum Biotechnologies](#) will invest \$83 million to establish a manufacturing site in Durham that will employ 202 people at an average salary of \$93,762 when fully operational.
- Pennsylvania-based [West Pharmaceutical Services](#), a manufacturer of drug-packaging and delivery components, will invest \$19 million over the next year to expand its production capacity in Kinston, adding about 90 new jobs to the plant’s current workforce of 425.
- [FUJIFILM Diosynth Biotechnologies U.S.A., Inc.](#) (FDB) has broken ground on a \$54 million, 31,778-square-foot expansion of its biomanufacturing facilities in Morrisville. The investment in its contract development and manufacturing organization (CDMO) business is part of a \$90 million Fujifilm Corporation commitment to meet growing customer demand for biopharmaceuticals. The expansion will increase cell culture manufacturing capacity by about 25 percent and microbial capacity by about 50 percent at the firm’s campus in Morrisville, **bringing 725 new jobs to the region by 2025**. It will include the addition of 2,000-liter single-use cell culture manufacturing trains, cell culture purification suites and new microbial recovery suites.

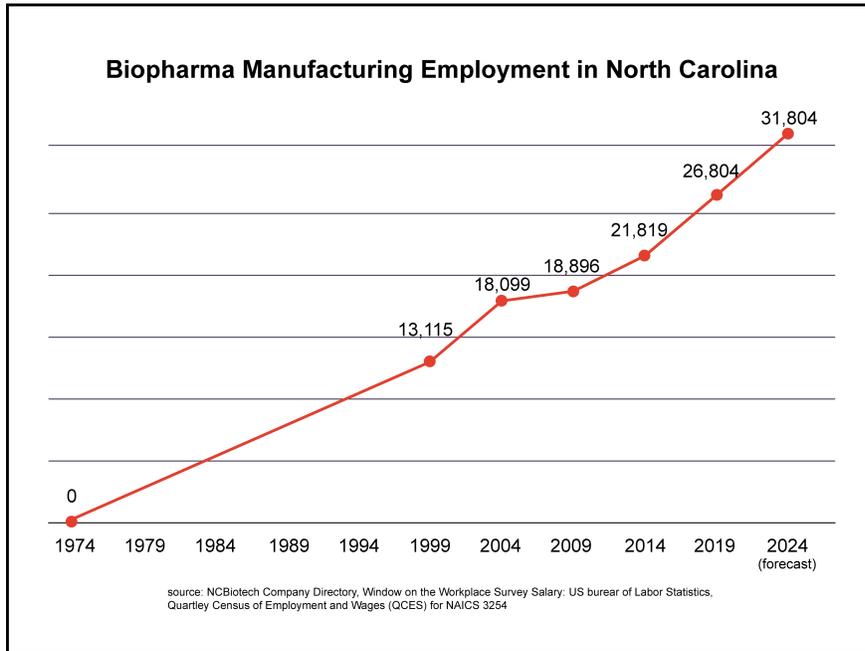
(Source: wraltechwire.com, Jim Shamp, NCBiotech Writer, February 2020 and Barry Teater, NCBiotech writer, March 2021)

Labor Market for Cell and Gene Therapy Workforce

The following workforce section will be organized in three parts: 1) findings from a “literature review” of existing workforce research, reports and articles documenting the demand for biomanufacturing technicians with cell and gene therapy (CGT) knowledge and skills and 2) findings from job postings data related to the demand for CGT technicians which will include data on numbers of job postings, top employers, top job titles, skills in demand, and education and experience desired by employers and 3) CGT job growth projections for North Carolina.

North Carolina Region Life Sciences Employment

North Carolina’s biopharma manufacturing workforce has grown to more than 26,800 employees, with average salaries of \$97,575. Employees working in the manufacturing and quality assurance/quality control areas at these companies make up over 60% (39% and 22% respectively) of employees at biopharma manufacturing sites. The Biopharma Manufacturing industry “has the potential to create more than 5,000 new jobs in North Carolina over the next five years. This level of demand will challenge, and likely exceed, the output of North Carolina’s existing biopharma education and training infrastructure. Companies have a need not only for more process technicians, but also for mid-level and site leadership positions.” (Source: *Window on the Workplace 2020: Workforce Training Needs for North Carolina’s Biopharma Manufacturing Industry*)



(Source: *Window on the Workplace 2020: Workforce Training Needs for North Carolina’s Biopharma Manufacturing Industry*; NC Biotech Company Directory, *Window on the Workplace Survey for number of jobs*)

Biologics for Clinical and Commercial Use

Biologics are produced from living organisms or contain components of living organisms. Biologics manufactured in N.C. include vaccines, industrial enzymes, purified proteins from human blood, diabetes therapeutics, regenerative medicines, and cell- and gene-based therapies. The following graphic lists some of the main companies in North Carolina who are driving growth in manufactured

biologics, including cell and gene therapies.

Company		
Ajinomoto North America	Humacyte Inc.	Pfizer Inc.
Archer Daniels Midland Co.	Huvepharma Inc.	Precision Biosciences Manufacturing Center for Advanced Therapeutics
AveXis Inc.	Ingredion Inc.	Promethera Biosciences LLC
Avoca Inc.	KBI Biopharma Inc.	Sagent Pharmaceuticals
Biogen	Keratin Biosciences Inc.	Seqirus, a CSL Company
BioResource International Inc.	Medicago USA Inc.	Stallergenes Greer
bluebird bio Inc.	Merck & Co. Inc.	Twin City Bio LLC
Collectis	Nitta Gelatin NA Inc.	Vertellus Specialties Inc.
FUJIFILM Diosynth Biotechnologies USA Inc.	Novex Innovations LLC	White Labs Inc.
Grifols	Novo Nordisk Pharmaceutical Industries LP	ZenBio Inc.
Hemo Bioscience Inc.	Novozymes North America Inc.	Zoetis Inc.

Source: Window on the Workplace 2020: Workforce Training Needs for North Carolina's Biopharma Manufacturing Industry

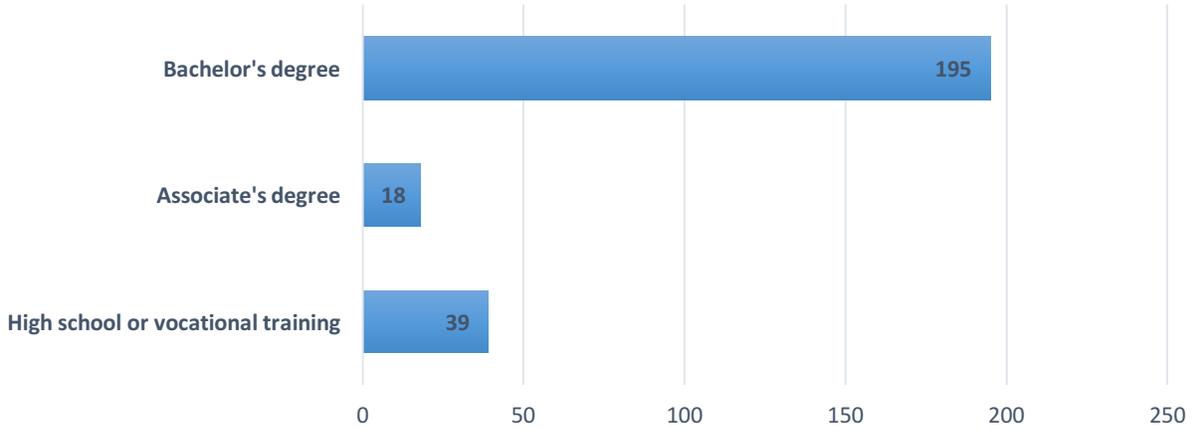
Findings from 2020 Job Postings Data in North Carolina

The following section displays job postings data related to demand for cell and gene therapy technicians in California for calendar year 2020 from Burning Glass/Labor Insight. There were **349 job postings in North Carolina in 2020** from Cell and Gene Therapy companies that employ technicians with cell and gene therapy related job titles.

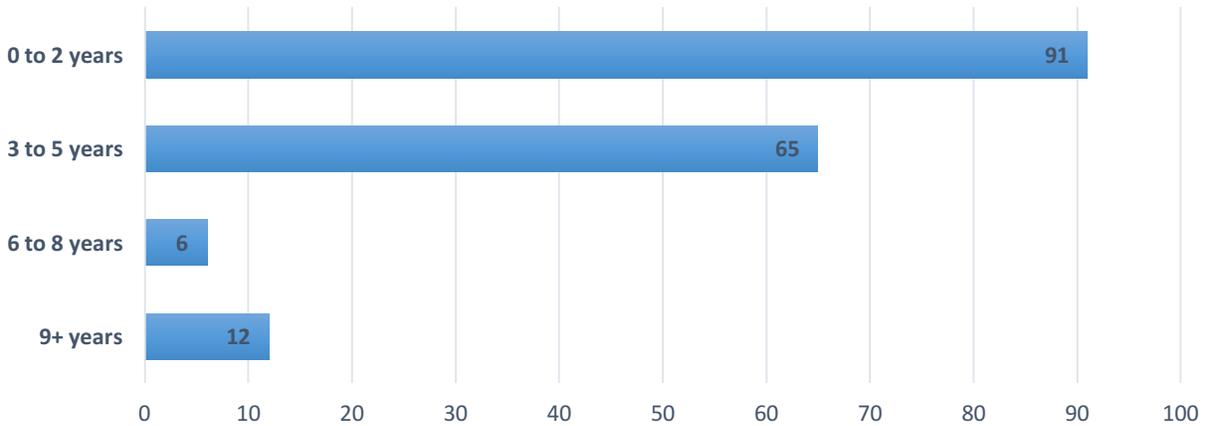
All data in the following charts is from Burning Glass/Labor Insight and covers the following information:

- Education level and experience employers are seeking
- Top employers in the state with most job postings
- Top job titles posted by cell and gene-therapy companies
- Top specialized skills and baseline/workplace skills most in demand by employers
- Trend line for these positions by region looking back 10 years

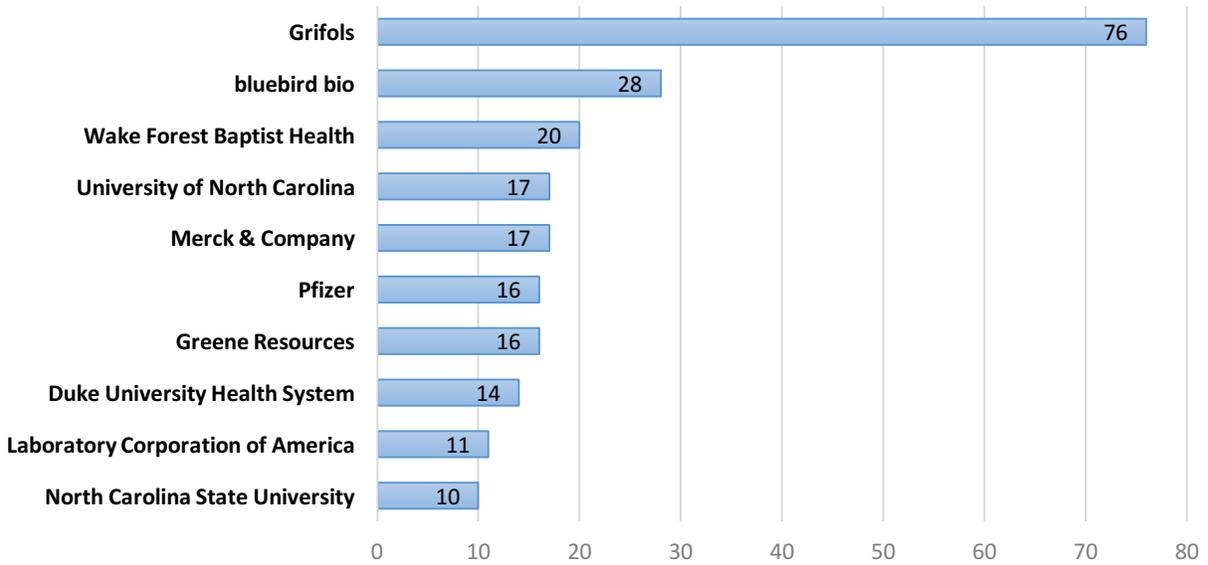
Education (Minimum Advertised)



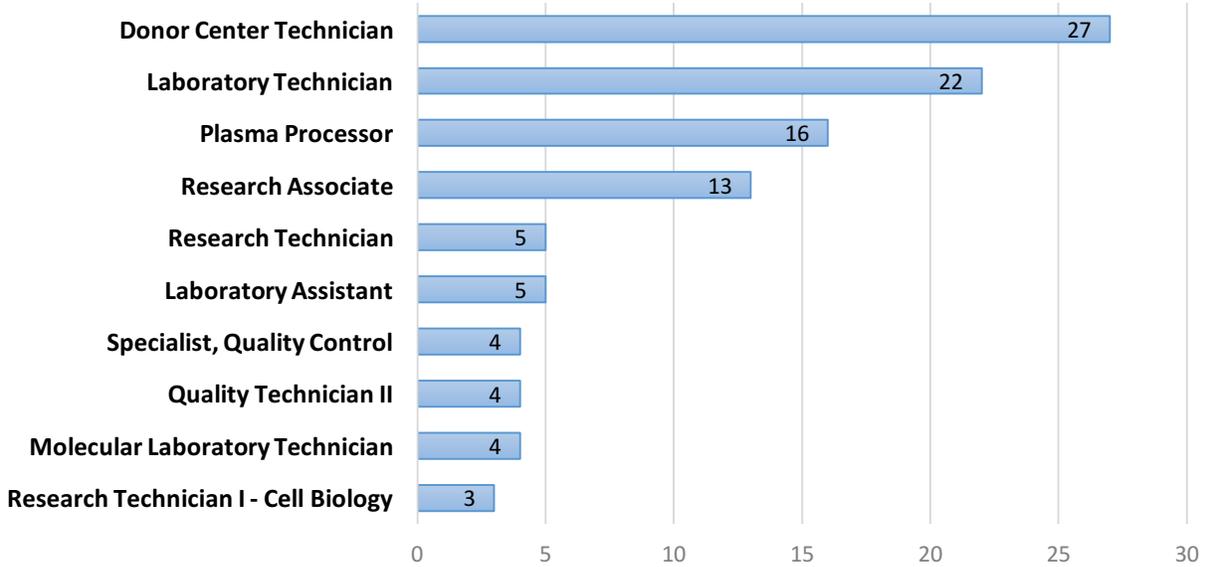
Experience Requirements for a Skill or Credential



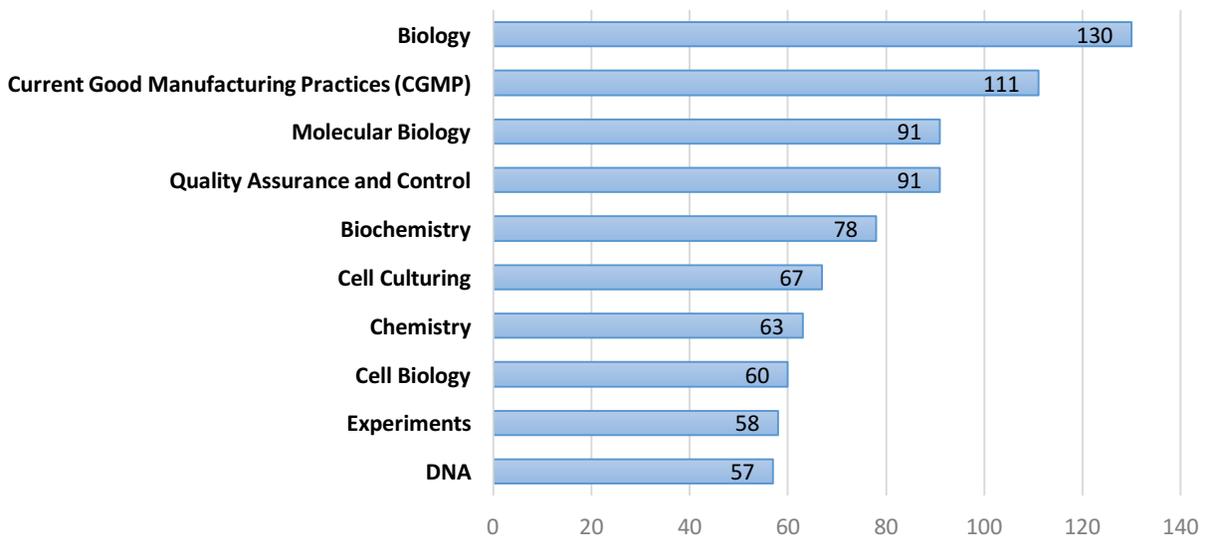
Top Employers



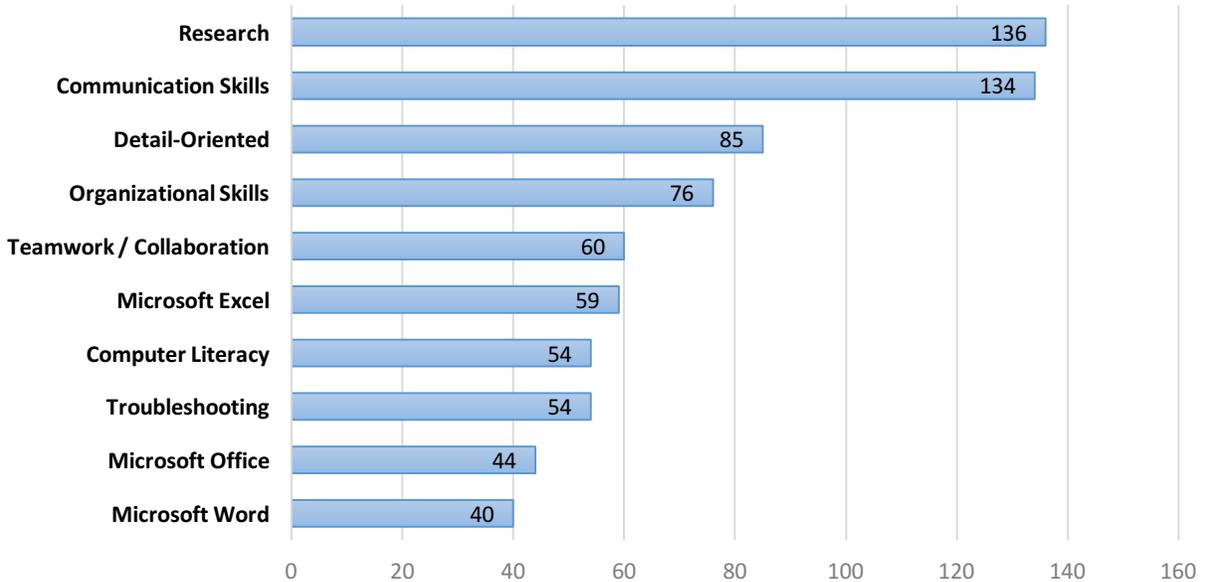
Top Job Titles

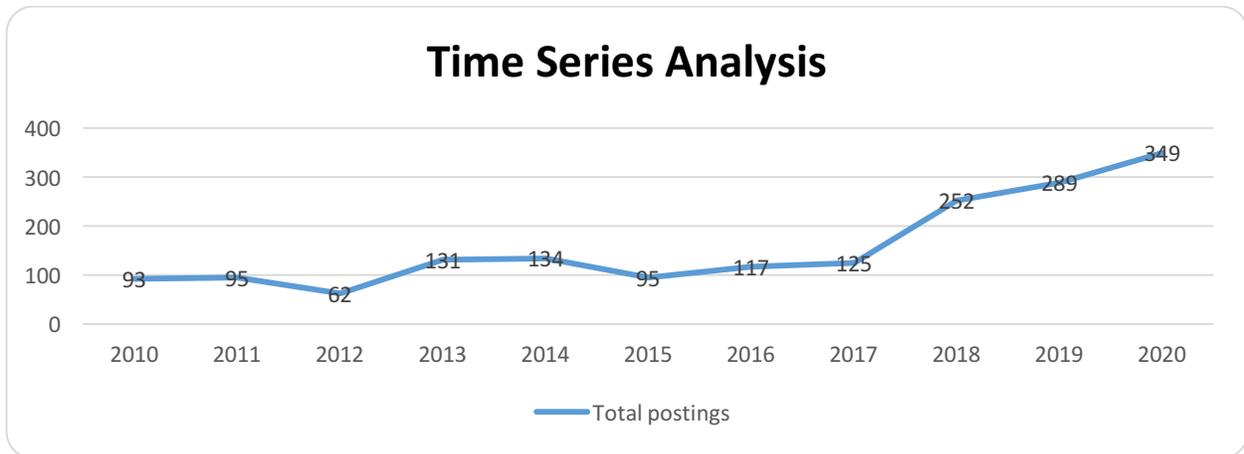


Top Specialized Skills



Top Baseline Skills





Job Postings for January - June 2021

For North Carolina, the first six months of 2021 showed strong job posting activity from cell and gene therapy (CGT) companies. During the period, there were 243 job postings from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles. If the trend for the first six months continued through the second half of the year, then the projected annualized number for the North Carolina would be 486 job postings, **which would be a 39% increase** compared to the 349 job postings in 2020.

Projections of Future Job Growth

Based on data from the North Carolina Biotechnology Center, the graphic below shows the companies projected to be adding new cell and gene therapy technician jobs in the near future:

Company	New Jobs	Projected Date
Fuji Diosynth	725*	2025
Lilly	462	
Audentes	209	
Grifols	300**	
Beam Therapeutics	200	By 2025
Merck	100	By 2023
KBI	200	
Huvepharma	10	
Thermo Fisher	500	2022
Taysha Gene Therapies	200	2023
Adverum	202	
Total	3,108	over next 5 years

Source: North Carolina Biotechnology Center

*25% increase from current employment

**15% growth from current employment

Activity Earns Top Accolade

The robust growth in pharmaceutical and biologics manufacturing in 2020 helped North Carolina score a notable media honor. [Business Facilities](#) magazine, a national publication serving corporate site selectors and economic development professionals, proclaimed North Carolina the “2020 State of the Year.” This marks the first time North Carolina has earned the magazine’s top honor, bestowed annually since 2007 to recognize the best states’ successes in winning projects that create capital investment and new jobs. “North Carolina is leveraging its advantages — including a prime logistics location, a steadily expanding skilled workforce and impressive higher education resources — to seal the deal on one big project after another,” said magazine Editor in Chief Jack Rogers. “The Tar Heel State has put down a marker that it’s ready to compete for a leadership position in the emerging growth sectors of the 21st century,” he added.

Boston/Massachusetts Region

Growth and Economic Expansion of Cell and Gene Therapy Companies

Boston / Cambridge ranked #1 in Top 10 U.S. Biopharma Clusters in 2020

Boston/Cambridge remains the nation's top biopharma cluster, thanks to number-one ranking in NIH funding (6,552 awards totaling \$3.711 billion), reflecting its critical mass of world-class universities and research institutions; and number-one ranking in lab space (35.2 million square feet), reflecting a wave of corporate activity. The region ranked second in patents (9,099) and Venture Capital (\$10.1 billion in 2019 and 2020) and ranked fourth in jobs (MassBio recorded 79,972 statewide jobs in 2019).

(Source: "Top 10 U.S. Biopharma Clusters", Genetic Engineering & Biotechnology News, www.genengnews.com, 2020)

According to a recent CBRE report entitled "[Markets Positioned for 'Century of Biology'](#)", rent for lab space in the Boston-Cambridge cluster, increased by double digits in 2019 and 1.9 million square feet of lab space is currently under construction there. The drug industry is booming, with life-sciences firms signing leases at a healthy clip and billions of dollars in venture capital pumping things up even more. BioMed Realty is planning a full overhaul of 601 Congress, converting all but the top two floors into life-sciences space. BioMed has experience on its side, having turned office buildings into lab space before, mostly in Kendall Square. *(Source: "Boston's in a lab-building boom. What will that mean for the city and its neighborhoods?", Boston Globe, 2/8/21).*

This reflects a striking shift in Boston's commercial real estate world. Developers — and sometimes owners of existing buildings — are turning away from traditional office towers toward life-sciences space, hoping to capture an industry that's growing fast even as stalwart insurance companies and law firms retreat from big offices. It's a trend that reflects the resilience of Boston's economy. Few cities are so well-positioned to capitalize on a wave of investment in drug-making and research, one that's spilling beyond the industry's longtime home in Cambridge's Kendall Square to the Seaport, the Fenway, Watertown, and Somerville.

Vibalogics, a global contract development and manufacturing organization (CDMO), announced in 2021 Phase I of its planned \$150 million investment in a late-phase clinical and commercial virotherapy manufacturing facility near Boston. The three-year investment plan includes the build out of a 110,000 square foot facility. The CDMO which specializes in the production of oncolytic viruses, viral vector

vaccines and viral vector gene therapy products, expects the site to be operational by the second half of 2021. The facility is expected to create 100 jobs initially, reaching 250 employees in the next four years.

(Source: Cell & Gene.com; 2021)

Bristol-Myers Squibb (BMS) is building a new cell therapy manufacturing facility in Devens, Massachusetts. The state-of-the-art facility will allow BMS to expand its global portfolio of complex biologic drugs, and is part of BMS's investment in the clinical and commercial manufacturing of cell therapies for patients with aggressive hematological cancers. The plant will produce Breyanzi, a cell-based gene therapy for certain types of large B-cell lymphoma, as well as other clinical and commercial cell therapy products. The facility is expected to come online in 2023 and **will create hundreds of jobs to support new operations and offer career development for employees** across the fields of biologics and cell therapies within a single campus.

(Source: "Bristol-Myers Squibb's New Cell Therapy Manufacturing Facility, Devens, Massachusetts", www.pharmaceutical-technology.com, 2021)

Supporting Mini-Clusters Outside Boston

More than [16.5 million square feet](#) of commercial lab space has been built in Massachusetts over the last 10 years – and it's all full. In Boston, only [0.8% of lab space is available](#), and across the river in East Cambridge – home to Kendall Square – there is a vacancy rate of 0%. With commercial rental prices in Kendall Square among the highest in the country, MassBio is encouraging companies to look outside the epicenter and towards the mini-clusters developing throughout the state. While Cambridge and Boston notoriously specialize in R&D, the availability and cost of space in the suburbs and beyond provide opportunities for the specialization of new capabilities like biomanufacturing.

(Source: "Supporting the Rise of Biomanufacturing in Massachusetts will Ensure the Sustainability of the State of Possible", MassBIO, February 2021)

The development of multiple, smaller manufacturing sites outside Boston has started to occur, including Pfizer Inc. in Andover, Takeda in Lexington, AbbVie in Worcester, Genzyme in Allston and Framingham, and Baxter International in Milford. Evidence of the trend was seen with the opening of several new biomanufacturing firms in Quincy in 2019 including AllCells and BIOMEDEX. MassBio, a biotech trade organization, also lists the city of Quincy among "its platinum-rated "Bio-Ready" communities. This is the top rating the trade organization gives to communities that it considers ready and welcoming to biotech business. Just 30 of Massachusetts' 351 cities and towns share this designation.

(Source: Patriot Ledger, February 2019, <https://www.patriotledger.com/news/20190213/biotech-businesses-choosing-quincy>)

Labor Market for Cell and Gene Therapy Workforce

The following workforce section will be organized in two parts: 1) findings from a “literature review” of existing workforce research, reports and articles documenting the demand for biomanufacturing technicians with cell and gene therapy (CGT) knowledge and skills and 2) findings from job postings data related to the demand for CGT technicians which will include data on numbers of job postings, top employers, top job titles, skills in demand, and education and experience desired by employers.

Massachusetts Life Sciences Employment

Massachusetts is home to one of the nation’s top regional bioscience clusters, centered in Boston and Cambridge, MA. The life sciences workforce is projected to grow by 16% or 12,000 jobs by 2024 after rising 35% in the decade ending last year. Yet, as the Massachusetts Biotechnology Education Foundation (MassBioEd) noted in its “[2019 Massachusetts Life Sciences Employment Outlook](#),” and [GEN Edge reported in December](#), a gap persists between the growing number of jobs and people skilled enough to fill them. (Source: “*Top 10 Life Sciences Jobs Most in Demand Over the Next Decade*,” *Genetic Engineering and Biotechnology News*, www.genengnews.com, 2021).

The Massachusetts life sciences industry is experiencing extraordinary growth in terms of scientific breakthroughs, technological advances, and venture capital investments. To fuel this expansion, it will need to grow the talent pipeline of qualified scientists, engineers, clinical and regulatory professionals, and others who drive this industry. Overall the supply of new students entering college in the state has flattened due to broad demographic trends. There has been a nationwide push over the past few years to encourage young people to pursue a major in Science, Technology, Engineering, or Mathematics (STEM). The number of college graduates with majors in these fields has increased over the past decade, but not at the rate necessary to continue the pace of growth that the life sciences industry has been displaying.

Hybrid careers—those that demand a high level of knowledge and expertise in two or more different areas—are on the rise. There is a high demand for people who understand molecular biology and can also write code to decipher large quantities of genomic data. **In biomanufacturing, there is a need for**

engineers and technicians who also possess a deep understanding of biological processes to design and continuously improve the large-scale manufacture of biological therapeutics.

Growing and sustaining the life sciences workforce should be recognized as the primary, over-arching mission of our leaders. Investment in STEM education, building awareness of the opportunities in the life sciences, and creating innovative pathways for non-traditional workers to enter the field are endeavors that will be rewarded by the sustained success of companies, a continuation of scientific breakthroughs, and development of novel therapies to treat and cure human disease. *(Source: 2019 Massachusetts Life Sciences Employment Outlook, Massachusetts Biotechnology Education Foundation (MassBioEd), 2019)*

The Massachusetts Life Sciences industry exceeded 70,000 employees for the first time in 2018. Since 2014, the life sciences industry in Massachusetts has grown at approximately double the rate of the state and U.S. economy. The Biopharma industry experienced the highest year-over-year employment growth in over a decade, adding over 4,300 new jobs from 2017 to 2018 for 6.4% growth. Biotech research & development (R&D) employment growth was nearly 50% over the past 10 years.

Industry job openings posted online exceeded 27,700 in 2017, second only to 2016. **Looking ahead, MassBioEd projects employment growth in the industry to reach almost 12,000 new workers between May 2017 and May 2023, a 6-year growth rate of 17.4%.** While impressive, it is somewhat below the six preceding years, during which the industry grew its workforce by 20.5%.

Amid such high growth, some impediments have arisen. Nearly two-thirds of industries surveyed by MassBioEd stated that the average time it takes to fill an opening at their organizations exceeded 2.5 months, with 30% reporting that the average time to fill openings was longer than 3 months. The economy-wide average in the region is about 1 month. This slow hiring rate is compounded by the fact that the four areas employers report the most difficulty with in onboarding qualified candidates – Research & Development, Regulatory Affairs, Quality, and Clinical Research – are also the top four functional areas in which organizations plan to expand in 2018.

To an extent, Massachusetts colleges and universities have responded to increased industry needs, as the number of awards issued increased by at least 50% at every degree level except Ph.Ds., which increased by 16%. However, the pace of growth since 2010 in entry level openings has generally outpaced the growth of graduates from industry-related programs. This problem is especially acute at

the Associate and Ph.D. levels, where the difference is significant. (Source: 2019 Massachusetts Life Sciences Employment Outlook, Massachusetts Biotechnology Education Foundation (MassBioEd), 2019 and 2018 Job Trends Forecast, Life Sciences Industry Massachusetts, MassBioEd, 2018).

Top Cell and Gene Therapy Companies in Massachusetts by Employment

Company	Employees as of Sept. 1, 2020	Company's Main Product/Service
Takeda Pharmaceutical Cambridge, MA	6,754	Focused on four therapeutic areas: oncology, rare diseases, neuroscience, and gastroenterology
Sanofi Cambridge, MA	4,200	Global biopharmaceutical company focused on human health
Biogen Inc. Cambridge, MA	2,749	Therapies for people with serious neurological and neurodegenerative diseases
Novartis Cambridge, MA	2,335	Broad range of medicines for a variety of diseases and conditions
Pfizer Inc. Cambridge, MA	2,200	Focus areas include internal medicine, rare diseases, inflammation & immunology, and oncology
Vertex Pharmaceuticals Inc. Boston, MA	2,200	Transformative medicines to help people with serious disease like cystic fibrosis
Charles River Laboratories Inc. Wilmington, MA	1,755	Pre-clinical research, discovery, safety and efficacy testing, clinical support, and manufacturing support
Quest Diagnostics. Marlborough, MA	1,700	Diagnostic information services
MilliporeSigma Burlington, MA	1,700	Focused on scientific discovery, biomanufacturing, and testing services
Bristol Myers Squibb Cambridge, MA	1,600	Mission is to discover, develop and deliver innovative medicines that help patients prevail over serious diseases
Total	27,193	

(Source: Boston Business Journal).

Expanding the Pool of Skilled Workers

As the biomanufacturing sector begins to grow and flourish, so does the demand for diverse skillsets. Biomanufacturing roles require different skillsets and education experience levels than biotech R&D. MassBio's sister organization, [MassBioEd](#), recently announced the launch of a new [apprenticeship program](#) which uses the "apprenticeship model of technical education, on the job paid training, and mentorship to create a new and diverse pool of skilled workers to fill the talent pipeline for Massachusetts's life sciences industry." MassBioEd is targeting biomanufacturing technicians as one of the occupations for its apprenticeship program. Educational programs such as these along with the

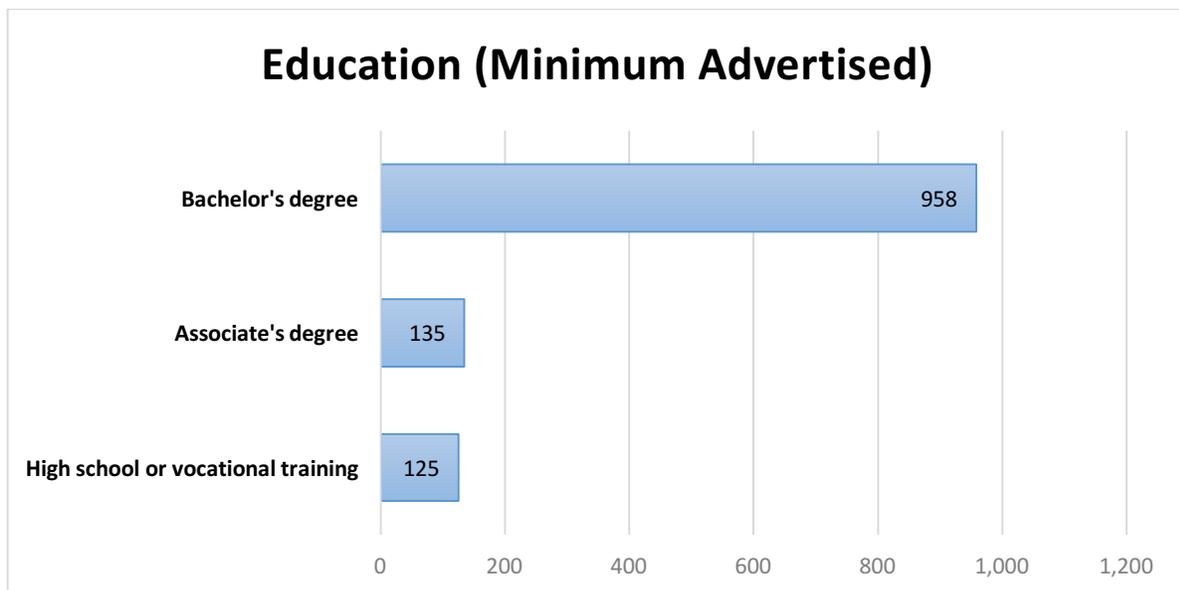
other excellent existing programs at our state’s universities and community colleges will help ensure Massachusetts has the pipeline of skilled workers necessary to attract biomanufacturing facilities to the state. (Source: “Supporting the Rise of Biomanufacturing in Massachusetts will Ensure the Sustainability of the State of Possible”, MassBIO, February 2021)

Findings from 2020 Job Postings Data in Boston/Massachusetts Region

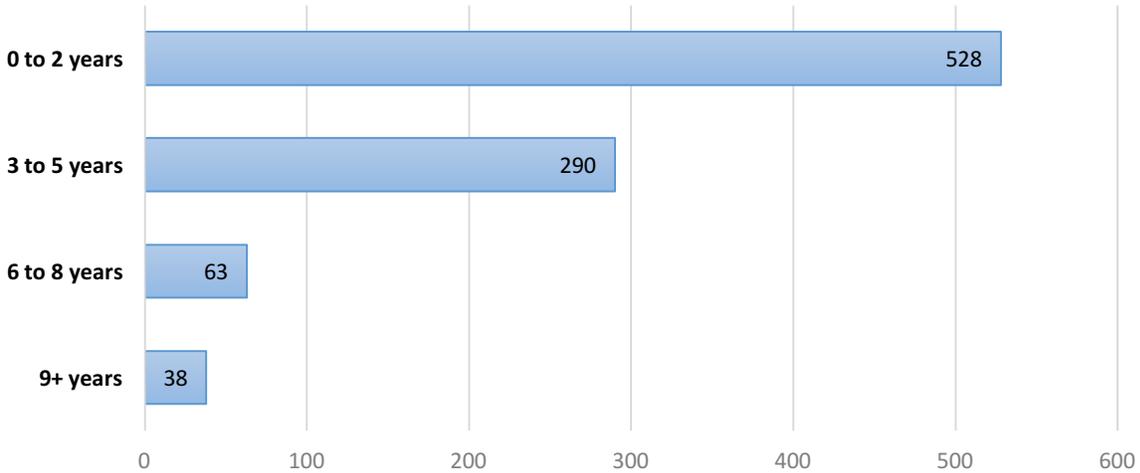
The following section displays job postings data related to demand for cell and gene therapy technicians in Massachusetts for calendar year 2020. **There were 1,221 job postings in the Boston/Massachusetts region in 2020** from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles.

The data in the following charts is from Burning Glass/Labor Insight and covers the following information:

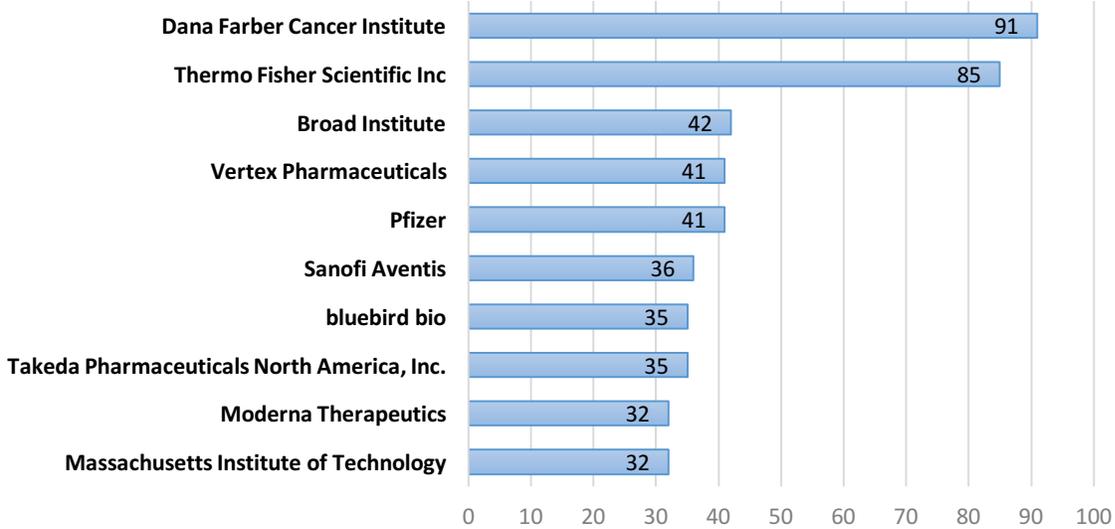
- Education level and experience employers are seeking
- Top employers in the state with most job postings
- Top job titles posted by cell and gene-therapy companies
- Top specialized skills and baseline/workplace skills most in demand by employers
- Trend line for these positions by region looking back 10 years



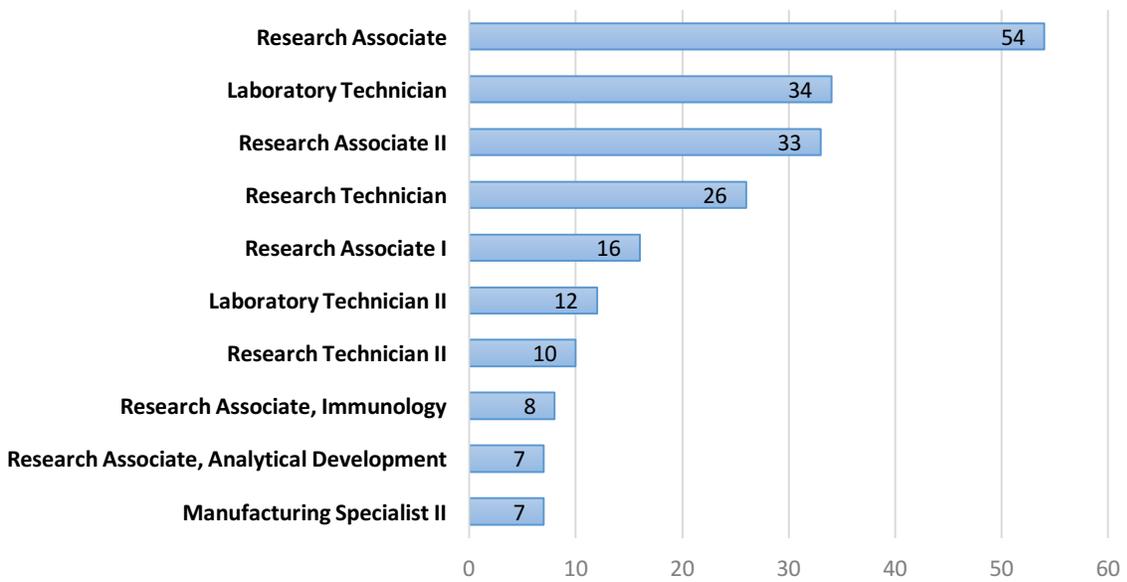
Distribution of Experience Requirements for a Skill or Credential



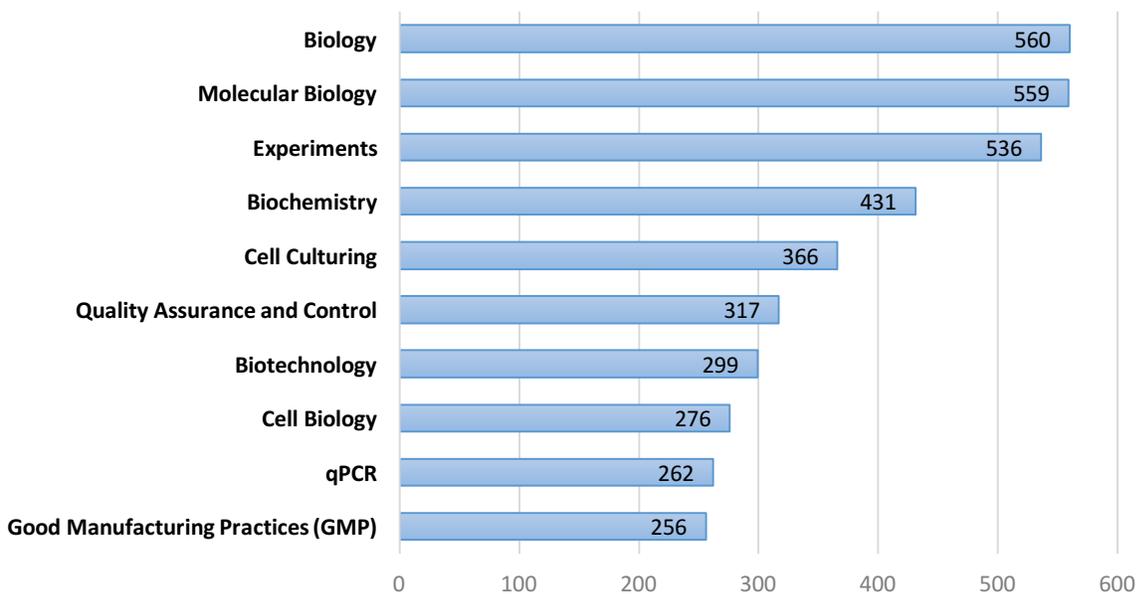
Top Employers

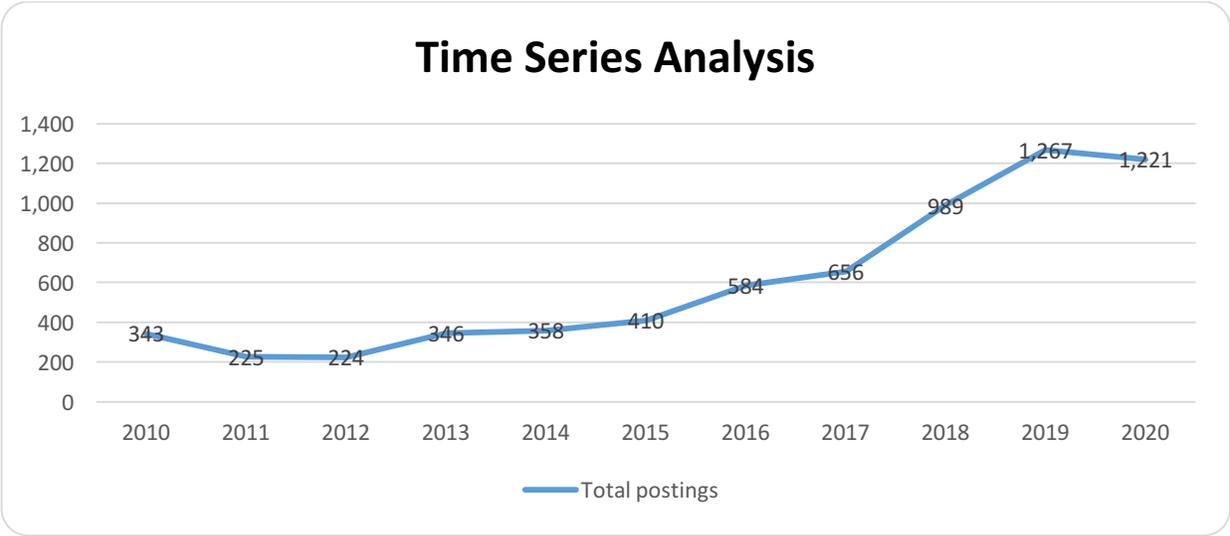
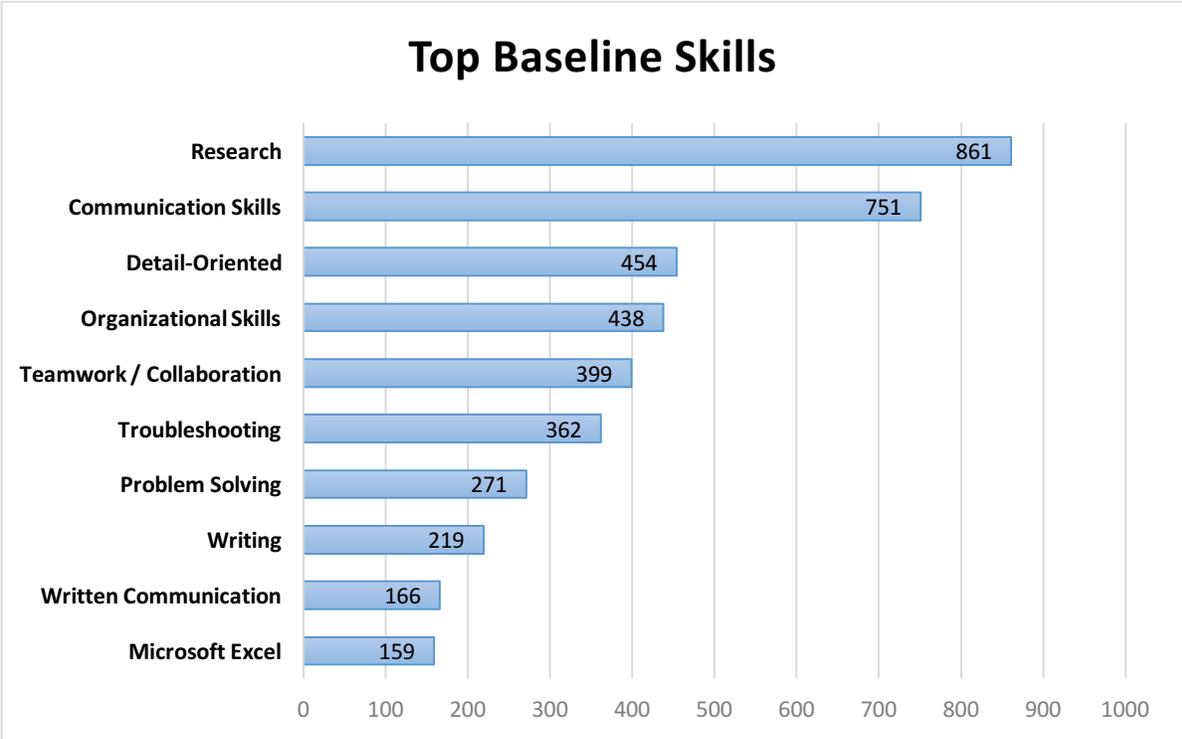


Top Job Titles



Top Specialized Skills





Job Postings for January - June 2021

For the Boston/Massachusetts region, the first six months of 2021 showed strong job posting activity from cell and gene therapy (CGT) companies. During the period, there were 890 job postings from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles. If the trend for the first six months continued through the second half of the year, then the projected

annualized number for the region would be 1,780 job postings, **which would be a 46% increase** compared to the 1,221 job postings in 2020.

Seattle/Washington Region

Growth and Economic Impact of Cell and Gene Therapy Companies

Seattle ranked #10 in Top 10 U.S. Biopharma Clusters in 2019 and Ranked #8 in 2020

In 2019, the University of Washington (UW) helped propel Seattle to sixth in the nation with patents with 2,170. The region places 10th in NIH funding (1,431 awards totaling \$894.4 million), in eighth place for lab space with 10 million square feet, and in ninth place with attracting Venture Capital, with \$282.4 million in 16 deals. Seattle's workforce of nearly 36,000, according to Life Sciences Washington, ranks the region in 11th place in the nation.

In 2020, after years of being sustained by top-flight universities and institutions, Seattle's life sciences cluster has enjoyed a good year from growing companies like immune therapeutics developer Alpine Immune Sciences which executed an \$865 million collaboration with AbbVie last year. Sana Biotechnology, whose treatments are based on its engineered cells, raised approximately \$675.6 million in gross proceeds in 2020 through an IPO, less than a year after completing a VC financing of more than \$700 million. Also going public recently is Silverback Therapeutics, which is applying its ImmunoTAC platform to develop tissue-targeted drugs for cancer chronic viral infections, and other diseases.

Seattle finished 2020 with approximately \$2.9 billion in Venture Capital deals, jumping three notches to a tie for fifth (with Greater Philadelphia) from eighth in 2019. Seattle also improved in NIH funding, to sixth with 1,894 awards totaling \$1.732 billion), but dipped to seventh in patents (2,336). The region ranked ninth in lab space (with 11.25 million square feet, according to Cushman & Wakefield) and 11th in jobs (35,914 as of 2019, according to statewide industry group Life Science Washington).

(Source: "Top 10 U.S. Biopharma Clusters", Genetic Engineering & Biotechnology News, genengnews.com, 2019, 2020)

Seattle's "Big R" (Research) Ecosystem

Amgen is partnering with a fast-growing Seattle-based personalized diagnostics and therapeutics developer, Adaptive Biotechnologies, to use its immune medicine platform to discover and develop antibodies against COVID-19. Adaptive Biotechnologies—which raised about \$321 million in net

proceeds when it went public in 2019—and Microsoft recently announced an expansion of a collaboration they recently formed which involves mapping population-wide adaptive immune responses to diseases. In 2019, Adaptive Biotechnologies also started an up-to-\$2.1 billion collaboration with Genentech, to develop personalized cancer cell therapies, and has plans to triple the size of its South Lake Union headquarters by 2021, signing a 100,000-square-foot lease.

Adaptive Biotechnologies partnership with Microsoft, based in suburban Redmond, also reflects a unique strength of Seattle’s life sciences industry—the home-grown presence of tech giants. Seattle’s South Lake Union is home to Amazon’s headquarters and a large campus for Google Cloud, while Google signed leases in January to expand in suburban Kirkland; Apple has grown its Seattle offices; Facebook has 18 offices in the region; and Salesforce expanded into Seattle’s North Lake Union when it completed its \$15.7 billion acquisition of Tableau Software in August.

“Our ‘Big R’ [research] ecosystem has been turbocharged in recent years by the explosion of tech in our region,” says Leslie Alexandre, President and CEO of Life Sciences Washington. That research ecosystem, she continues, is led by the University of Washington, the region’s leading public university for R&D expenditures. The University of Washington is preparing to open its \$230-million Population Health Initiative building later this year. The Bill and Melinda Gates Foundation funded \$210 million of the cost, with \$15 million coming from Washington state.

The research ecosystem also includes the Fred Hutchinson Cancer Research Center, the Allen Institute, and Institute for Systems Biology—plus global health institutions such as the Bill and Melinda Gates Foundation and the Program for Appropriate Technology in Health (PATH). “The research productivity of these organizations and many others has spawned hundreds of life sciences companies throughout the greater Puget Sound region and attracted components of others,” Alexandre notes. “The most recent crop of startups includes standouts in cancer immunotherapies, [treatments for] infectious diseases and neurodegenerative disorders, and cell and gene therapies.”

Other recent regional developments include:

- Silverback Therapeutics, completed a \$78.5 million investment round, with proceeds set to support development of a treatment candidate for HER2-expressing solid tumors. The company plans to advance its pipeline of immune-modulating ImmunoTAC™ drug conjugates, therapeutic candidates targeting previously inaccessible disease pathways.
- Juno Therapeutics, the cancer immunotherapy developer that began as a Seattle startup, was bought by Celgene for \$9 billion in 2018.
- In 2020, Bristol-Myers Squibb completed its \$74 billion purchase of Celgene, growing its

workforce to more than 1000 people.

- Immune Design was acquired by Merck & Co. for \$300 million.

(Source: "In Praise of Lesser-Sung Life Sciences Clusters", genengnews.com, 6/25/20).

Future Innovation in Seattle

Gene editing using CRISPR has already made it into human trials, but researchers at [Fred Hutchinson Cancer Research Center \(FHCRC\)](#) are using the technology to create tailored antibodies by manipulating B cells. They won't replace vaccines, but this therapy could be used for complex diseases, said [Justin Taylor](#), assistant member at the FHCRC who works on B cells. "I think the 2020s will prove to be the decade of cell and gene therapy," said [Keith Jerome](#), a [FHCRC](#) virologist. "Not only for HIV, but for other infectious diseases, cancer and much more."

Artificial intelligence and other technology will play a larger role in advancing therapies, many predict. "As research organizations like [Fred Hutchinson](#) and others generate more and more data, we will finally be able to leverage new machine learning approaches to gather specific insights," said [Raphael Gottardo](#), scientific director of the Translational Data Science Integrated Research Center at the FHCRC. "Computational biology will be the key to helping discover and validate new therapeutics or repurposing old drugs to treat new diseases."

(Source: Tech will drive change in health care throughout next decade, Puget Sound Business Journal, 2020)

Labor Market for Cell and Gene Therapy Workforce

The following workforce section will be organized in two parts: 1) findings from a "literature review" of existing workforce research, reports and articles documenting the demand for biomanufacturing technicians with cell and gene therapy (CGT) knowledge and skills and 2) findings from job postings data related to the demand for CGT technicians which will include data on numbers of job postings, top employers, top job titles, skills in demand, and education and experience desired by employers.

Seattle/Washington Life Sciences Employment

The state of Washington had 1,144 life science companies in 2020, up from 888 four years ago, Life Science Washington estimates. Companies like Seattle Genetics, Juno Therapeutics and Adaptive Biotechnologies are leading the charge in Seattle and **as many as 5,000 life science businesses will be in Washington by 2030.**

Bothell City Manager [Jennifer Phillips](#) is planning on Bothell’s life science sector growing in the next decade. One aspect of that is the city’s plan to turn the 735-acre Canyon Park — already home to Seattle Genetics, Juno Therapeutics and Philips — into a bigger biotech hub. There are more than 10,000 health care related jobs in Bothell, which represents 30 percent of the city’s employment. “It’s planning for opportunity,” she said. “What we’re telling the businesses is we want you here and we want you to be successful here.”

(Source: “Tech will drive change in health care throughout next decade”, Puget Sound Business Journal)

Top Cell and Gene Therapy Companies in Seattle by Employment

Business Name	Local Full Time Employees 2019	Global Employees 2019
Fred Hutchinson Cancer Research Center Seattle, Wa	3,556	
Seattle Genetics Bothell, Wa	1,300	1,600
Juno Therapeutics Seattle, Wa	705	8,852
Nanostring Technologies Seattle, Wa	400	575
Adaptive Biotechnologies Seattle, Wa	352	453
AGC Biologics Bothell, Wa	306	805
Alder BioPharmaceuticals Bothell, Wa	195	202
Omeros Corp. Seattle, Wa	168	236
ZymoGenetics Seattle, Wa	150	23,300
Total	7,132	

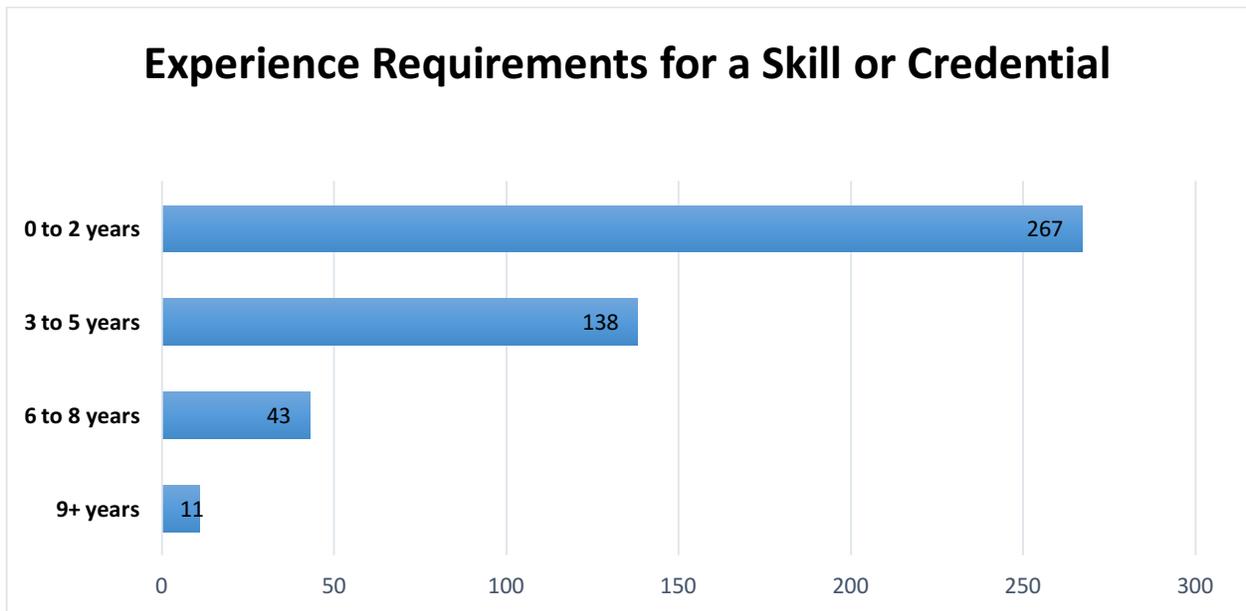
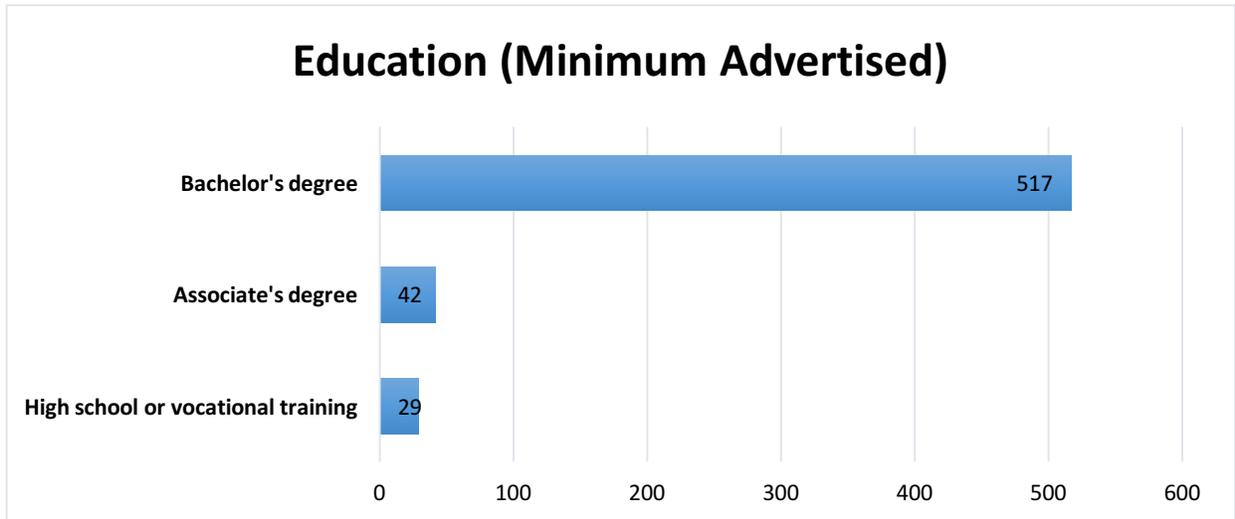
(Source: Puget Sound Business Journal).

Findings from 2020 Job Postings Data in Seattle/Washington Region

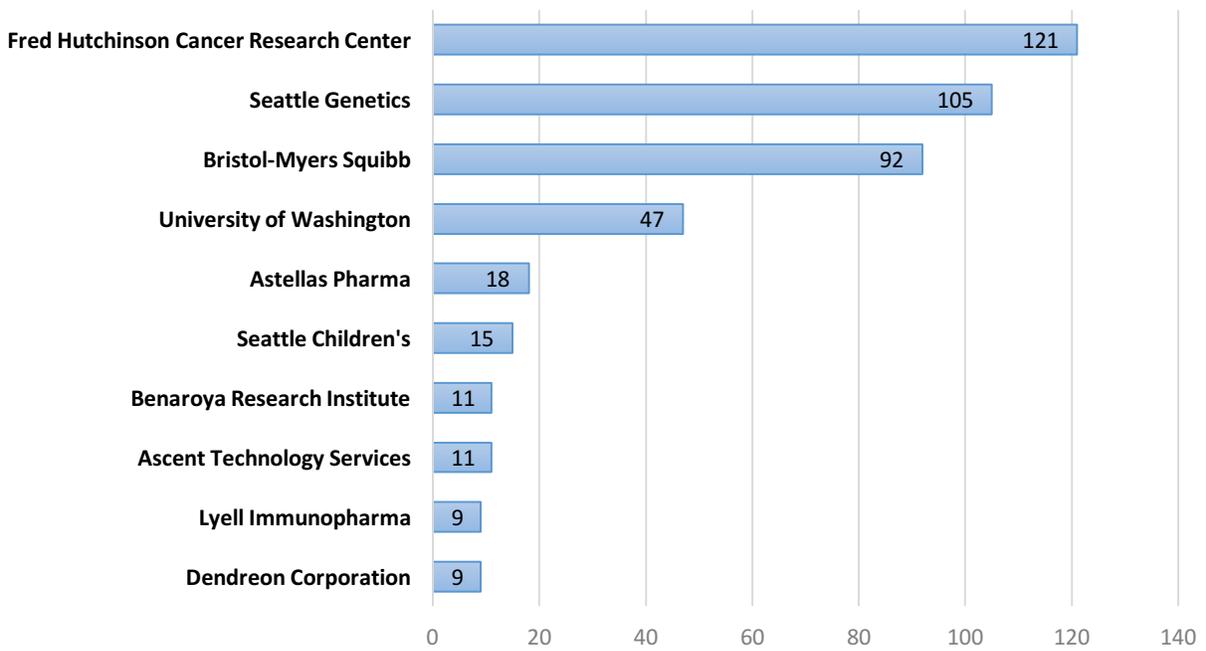
The following section displays job postings data related to demand for cell and gene therapy technicians in California for calendar year 2020. **There were 588 job postings in the Seattle/Washington region in 2020** from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles.

The data in the following charts is from Burning Glass/Labor Insight and covers the following information:

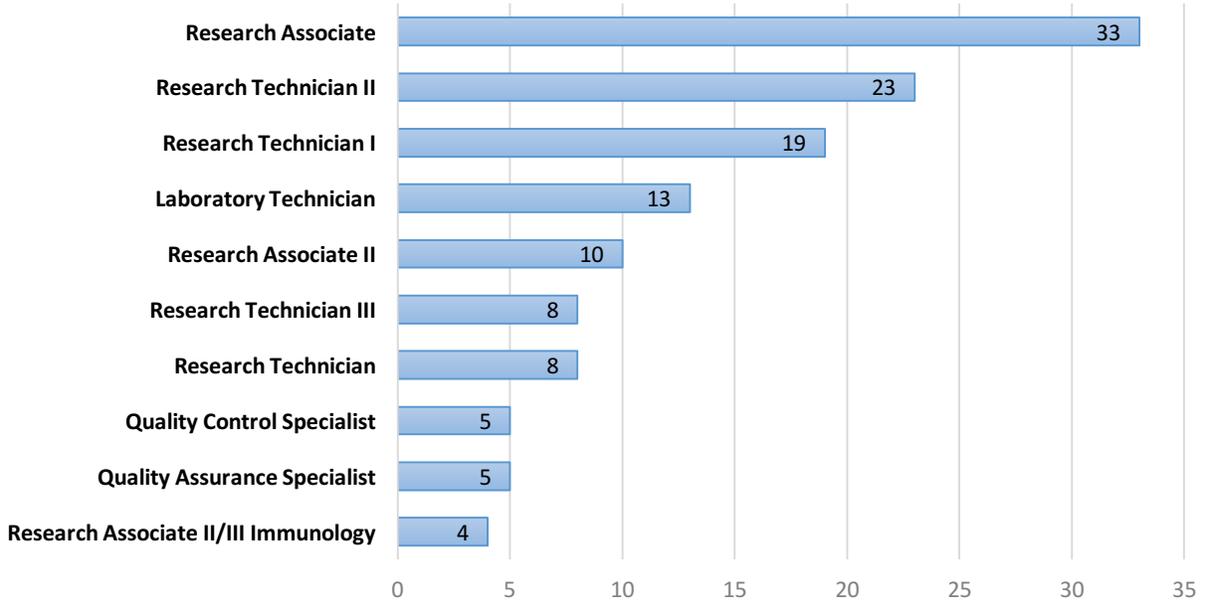
- Education level and experience employers are seeking
- Top employers in the state with most job postings
- Top job titles posted by cell and gene-therapy companies
- Top specialized skills and baseline/workplace skills most in demand by employers
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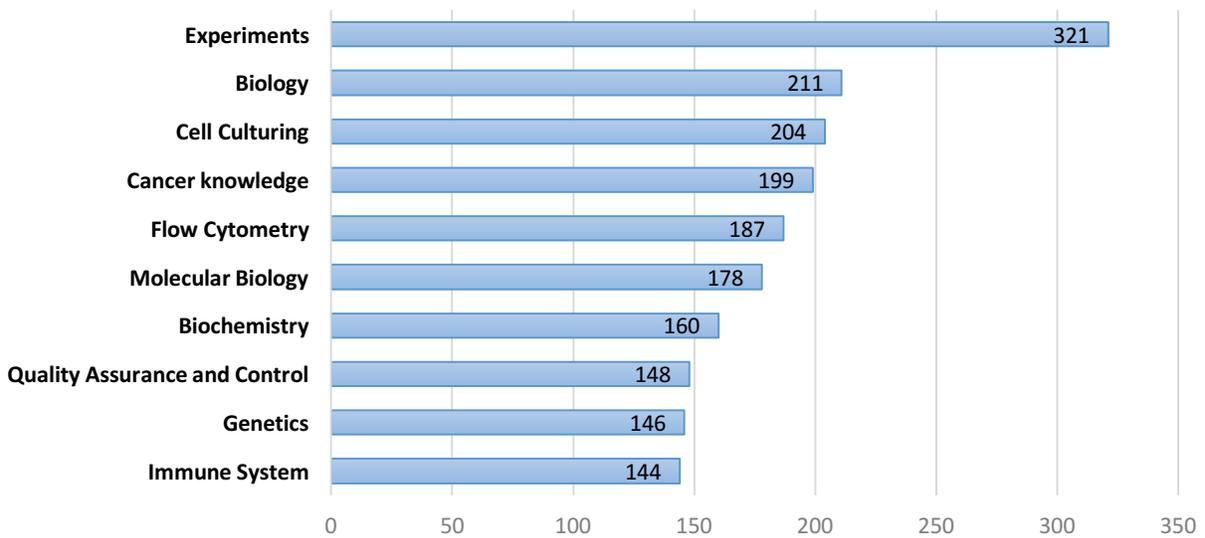
Top Employers



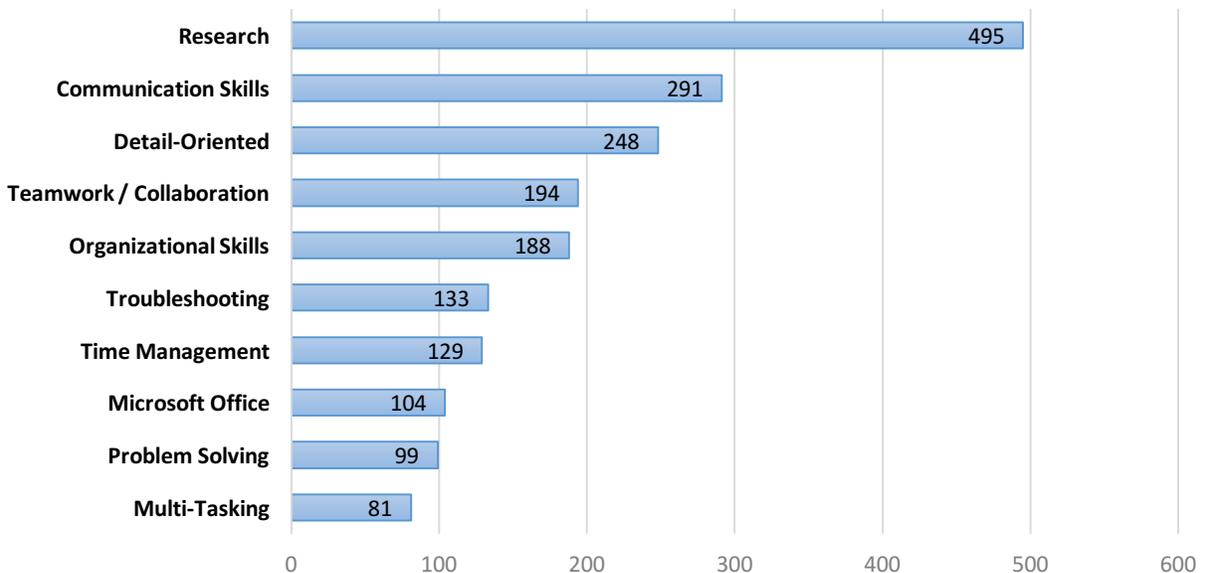
Top Job Titles



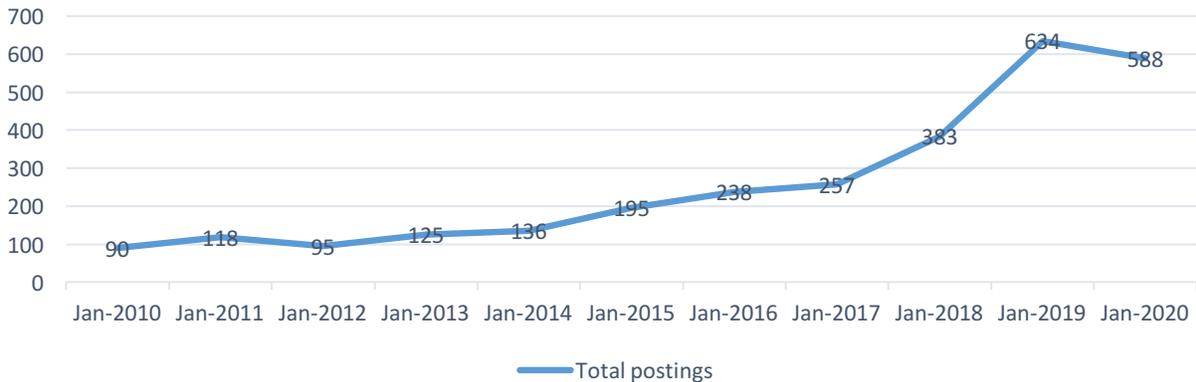
Top Specialized Skills



Top Baseline Skills



Time Series Analysis



Job Postings for January - June 2021

For the Seattle/Washington region, the first six months of 2021 showed strong job posting activity from cell and gene therapy (CGT) companies. During the period, there were 349 job postings from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles. If the trend for the first six months continued through the second half of the year, then the projected annualized number for the region would be 698 job postings, **which would be a 19% increase** compared to the 588 job postings in 2020.

San Francisco Bay Region

Growth and Economic Impact of Cell and Gene Therapy Companies

Life Sciences Firms and Economic Impact

- As a crucial economic driver, California life sciences companies are the second largest technical employment sector in the state.
- Biomedical exports account for \$24.3 billion and the industry and employees paid nearly \$18 billion in federal, state and local taxes.
- Home to **1,805 biotechnology and pharmaceutical companies**, which produce new technologies to improve patient care and boost the state's economy.

Investments

- **No. 1 in venture capital life sciences investments:** California continues to secure the most Venture Capital (VC) life sciences funding in the nation, **with \$6.5 billion in 2019**. Massachusetts is the next closest state, with nearly \$4.2 billion.

- **No. 1 in NIH grants:** California scientists received almost **\$4.5 billion in NIH research grants** (8,380 awards) in federal fiscal year 2019—the most of any state in the nation. Massachusetts received \$2.96 billion and New York \$2.83 billion.
- **No. 1 in clinical trials:** California is home to **nearly one quarter of all North American clinical trials**. Public and private financial support for clinical research are critical to supporting and expanding the number and reach of clinical trials. Private industry is still the single largest funder of clinical trials in California.

David Crean, Managing Director for Objective Capital Partners commented on the importance of investments in this growing sector: “We have seen strong spending towards innovative technologies and platforms such as **gene and cell therapies pursuing diseases in oncology, CNS, and rare diseases**. We have also observed COVID as a contributor to growth, despite some slowdown within parts of the sector, and COVID-19 almost becoming a new disease category in its own right with its own therapeutics and vaccines. Continued investment is the lifeblood of this sector and the foundation for early stage research.” (Source: *2020 California Life Sciences Sector Report, California Life Sciences Association (CLSA), 10/7/2020*).

San Francisco Bay Area ranked #2 in Top 10 U.S. Biopharma Clusters in 2020

The Bay Area improved in four of the five criteria since 2019, climbing from fourth to third in jobs (145,235, according to statewide life sciences industry group BIOCOM), and from third to second in lab space (33.1 million square feet, according to Cushman & Wakefield). **The region led the nation in patents (12,777) and Venture Capital (\$10.75 billion in 2019 and 2020)**. The Bay Area remained fourth in NIH funding (4,748 awards totaling \$2.474 billion). The largest VC award was the \$493 million Series C completed in April 2020 by Lyell Immunopharma, a developer of cell-based immunotherapies for any cancer, with a focus on CAR-Ts and solid tumors. Other major developments in the region include:

- Genentech (South San Francisco, CA) won approval for a near-doubling of space at its headquarters campus to 9 million square feet from 4.7 million. (Source: “*Top 10 U.S. Biopharma Clusters*”, *genengnews.com, 2020*)
- Bayer (Berkeley, CA) will build a Cell Culture Technology Center, a \$150 million investment. (Source: *Biospace.com, 2019*)
- Orchard Therapeutics (Fremont, CA) will build out a 150,000 square foot gene therapy manufacturing facility (Source: *BBC Newswire, 2018*)

Labor Market for Cell and Gene Therapy Workforce

The following workforce section will be organized in two parts: 1) findings from a “literature review” of existing workforce research, reports and articles documenting the demand for biomanufacturing technicians with cell and gene therapy (CGT) knowledge and skills and 2) findings from job postings data

related to the demand for CGT technicians which will include data on numbers of job postings, top employers, top job titles, skills in demand, and education and experience desired by employers.

San Francisco Bay Region Life Sciences Employment

- **No. 1 in jobs:** Biotech and medical device employment in California combined grew 7.4% between 2013 and 2018.
- **The Bay Area led the state with 87,441 direct life sciences jobs (an increase of nearly 5,000 from prior year).** Los Angeles County followed with 59,061 (increase of almost 2,000), while San Diego County directly employed 51,419 (increase of almost 3,000) and Orange County reported 48,173 direct life sciences jobs (increase of over 3,000).
- The **biopharmaceutical sector** is part of the thriving life sciences sector in California with 678 biopharmaceutical manufacturing businesses in the state. The San Francisco Bay Area has over 18,000 biopharmaceutical jobs, with biopharmaceutical manufacturing jobs representing 31% of all life science jobs in the Greater San Francisco Bay Area.

(Source: California Life Sciences Association, 2019 and 2020 California Economic Impact Report: Data Book, BioCom; 2020 California Life Sciences Sector Report, California Life Sciences Association (CLSA).

Economic multiplier (indirect job creation)

- For every one worker employed in the biopharmaceutical manufacturing industry another 4.9 jobs are generated across a range of other industries.
- The economic spillover of biopharma manufacturing is significant, creating demand for construction jobs like electricians, instrumentation technicians, plumbers, carpenters, and millwrights.
- The biopharma manufacturing industry relies on other manufacturers for inputs into its production process, including industry jobs in packaging, labeling and printing, electronics, computers, communication equipment, and production equipment.

(Source: Biopharmaceutical Manufacturing in the U.S.: Making Cutting-Edge Medicines Today and Leading the Way on Medicines of Tomorrow, TEconomy Partners, March 2019)

Earnings

- Biopharmaceutical manufacturing has higher wages than other types of manufacturing and private industries overall.
- Biopharma manufacturing wages are 72% greater than the average wage for all U.S. manufacturing. In 2017, the average yearly salary for all manufacturing workers was \$66,840 and \$115,010 for biopharmaceutical manufacturing workers.

(Source: Biopharmaceutical Manufacturing in the U.S.: Making Cutting-Edge Medicines Today and Leading the Way on Medicines of Tomorrow, TEconomy Partners, March 2019)

Economic Output of Biopharmaceutical Manufacturing in California and Bay Area in 2019				
	Output	Value Added	Labor Income	Foreign Exports of Products and Services
California	Nearly \$125 billion	Over \$73 billion	Over \$28 billion	\$21.5 billion
Bay Area	Over \$69.5 billion	Over \$45 billion	Nearly \$7 billion	N/A

(Source: 2020 California Economic Impact Report: Data Book, BioCom)

Largest Biopharma Companies in the San Francisco Bay Area by Employment

Business Name	Bay Area Employees	Sample of Research Fields
Genentech South San Francisco, CA	10,500	Oncology, immunology, ophthalmology, neuroscience, metabolism, infectious diseases
Gilead Sciences Inc. Foster City, CA	4,000	HIV/AIDS, liver diseases, hematology/oncology, inflammation
BioMarin Pharmaceutical Novato, CA	1,950	Phenylketonuria (PKU), achondroplasia, hemophilia A, hereditary angioedema
Bayer Berkeley, CA	1,163	Cardiovascular disease, oncology, hematology, gynecology
Amgen South San Francisco, CA	650	Oncology, cardiometabolic disorders, inflammation
Total	18,263	

(Source: San Francisco Business Times, May 2020).

Genentech, based in South San Francisco, won approval for a near-doubling of space at its headquarters campus to 9 million square feet from 4.7 million. **That could enable up to 12,550 more employees in addition to the roughly 10,000 based there in 2020.** (Source: "Top 10 U.S. Biopharma Clusters", *genengnews.com*, 2020)

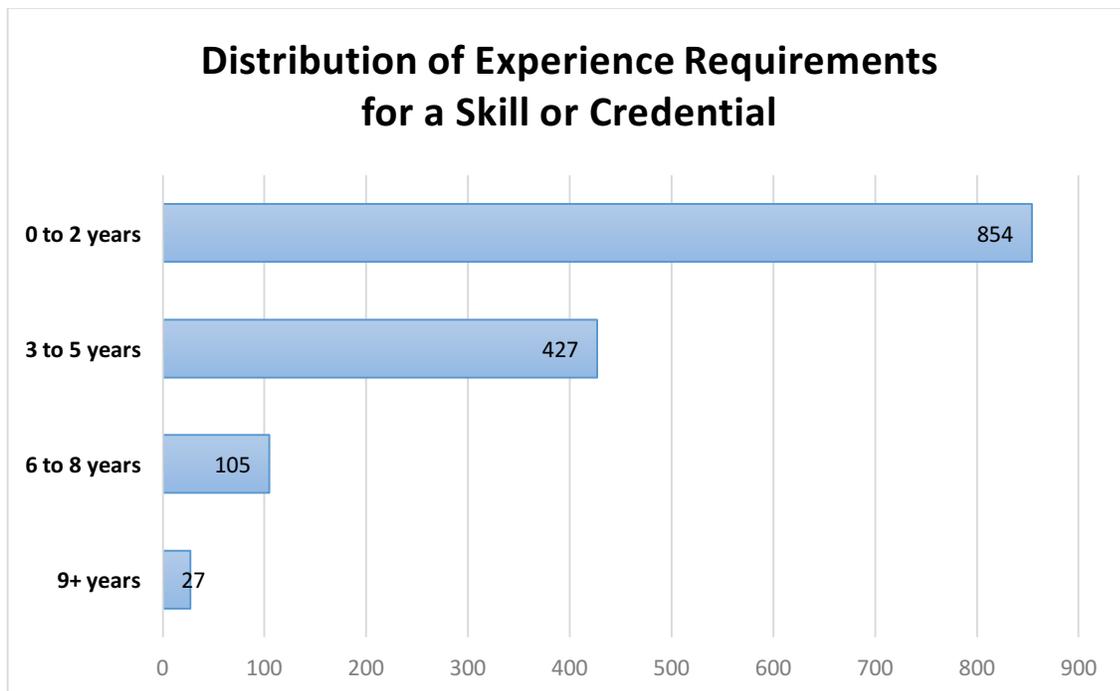
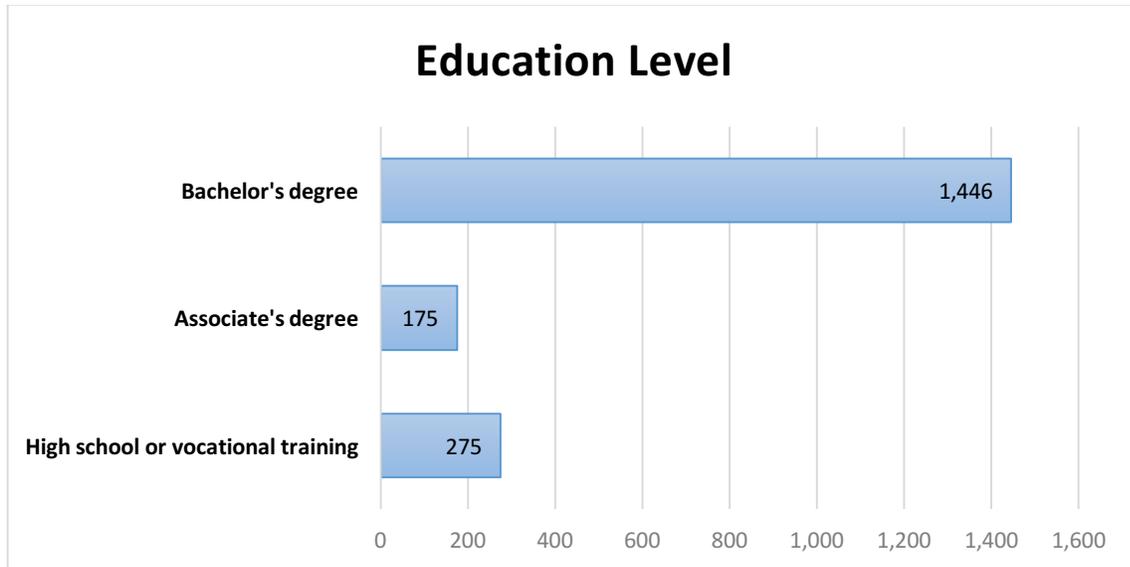
Findings from 2020 Job Postings Data in California

The following section displays job postings data related to demand for cell and gene therapy technicians in California for calendar year 2020. **There were 1,900 job postings in California in 2020** from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles.

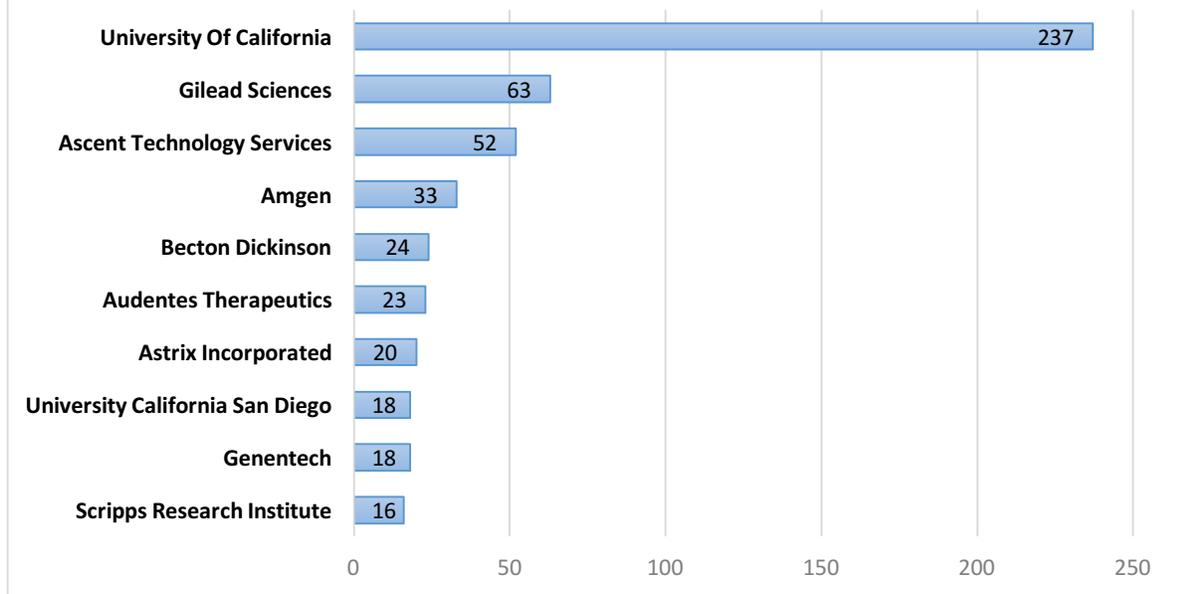
The data is from Burning Glass/Labor Insight and covers the following information:

- Education level and experience employers are seeking
- Top employers in the state with most job postings

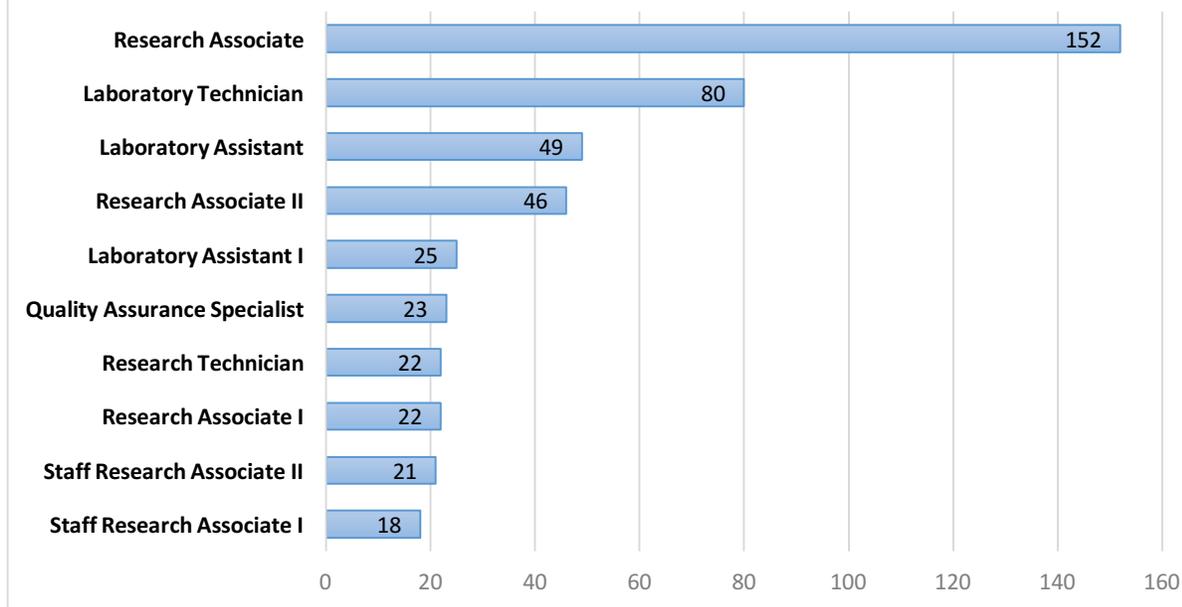
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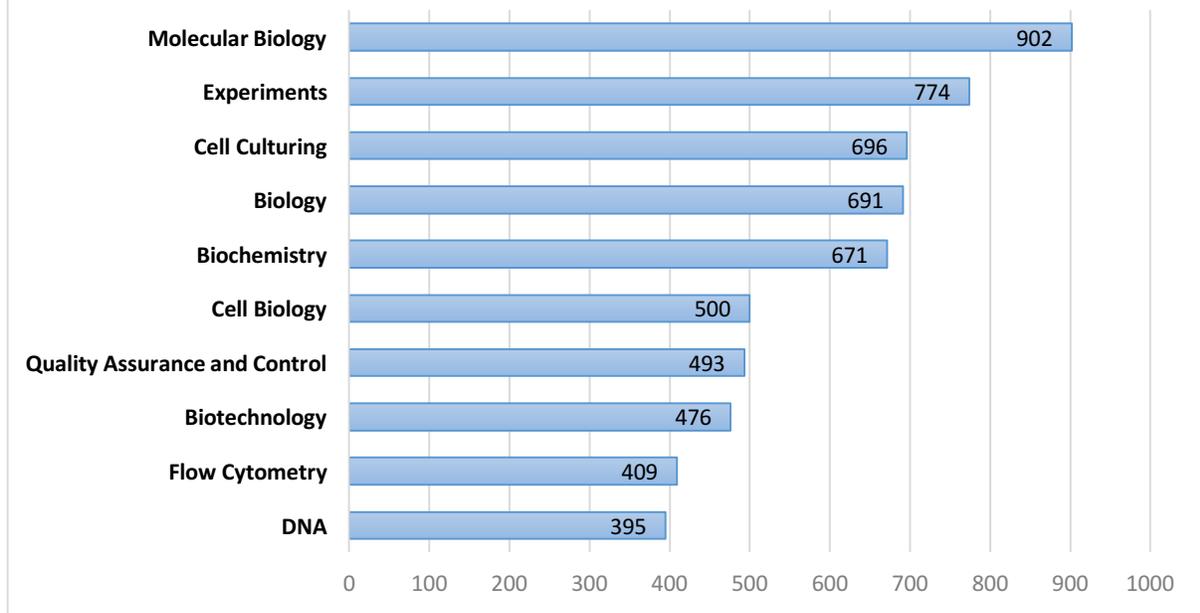
Top Employers



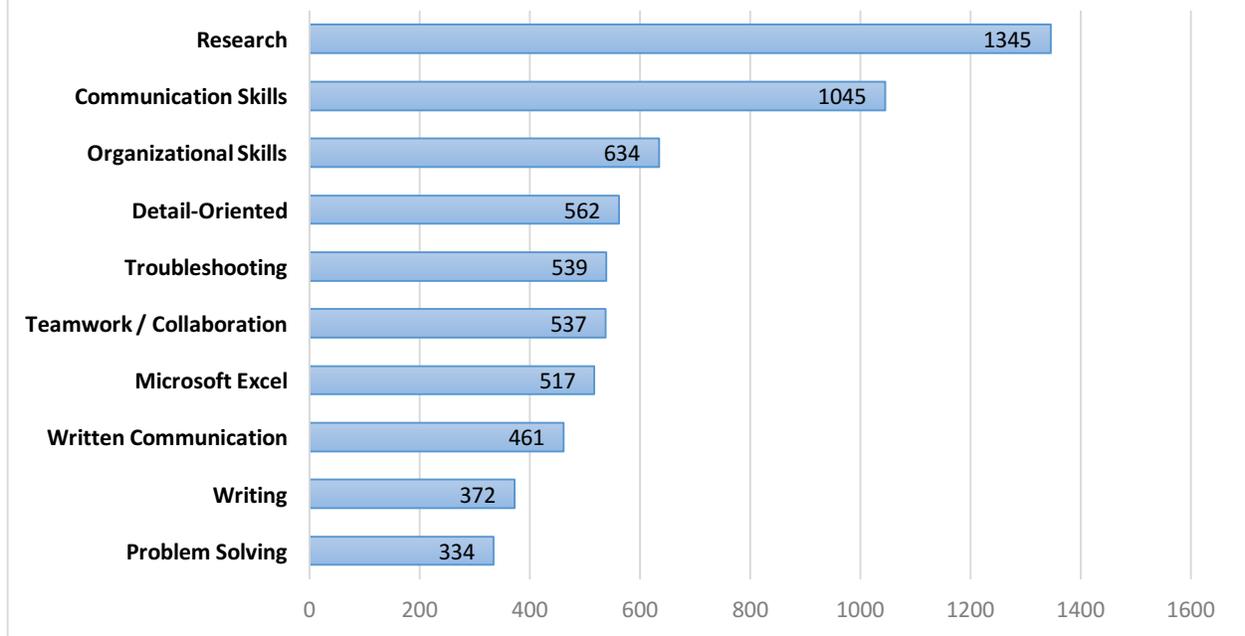
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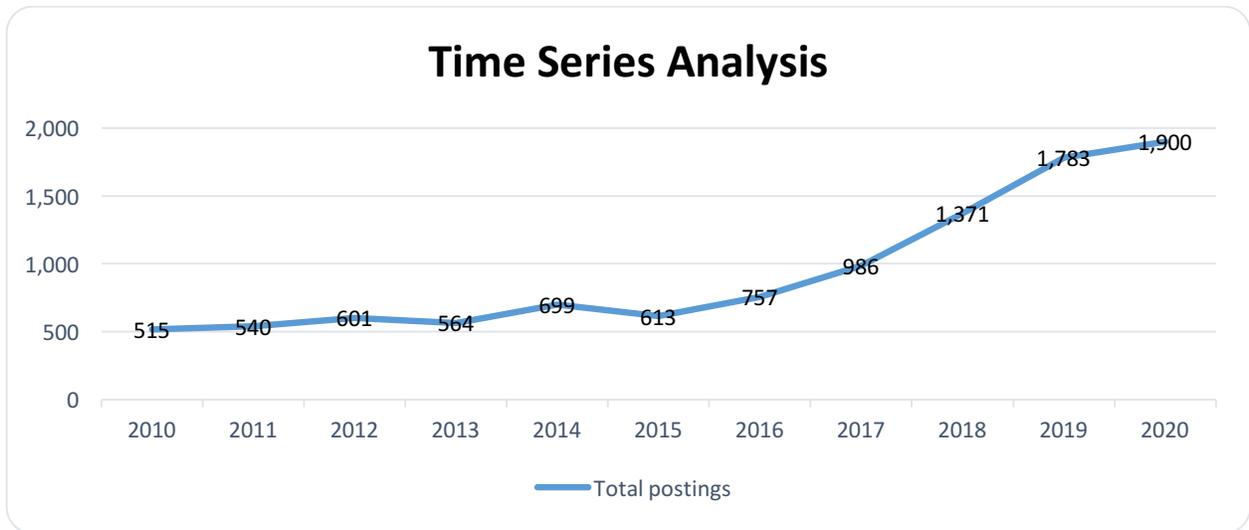


Top Specialized Skills



Top Baseline Skills





Job Postings for January - June 2021

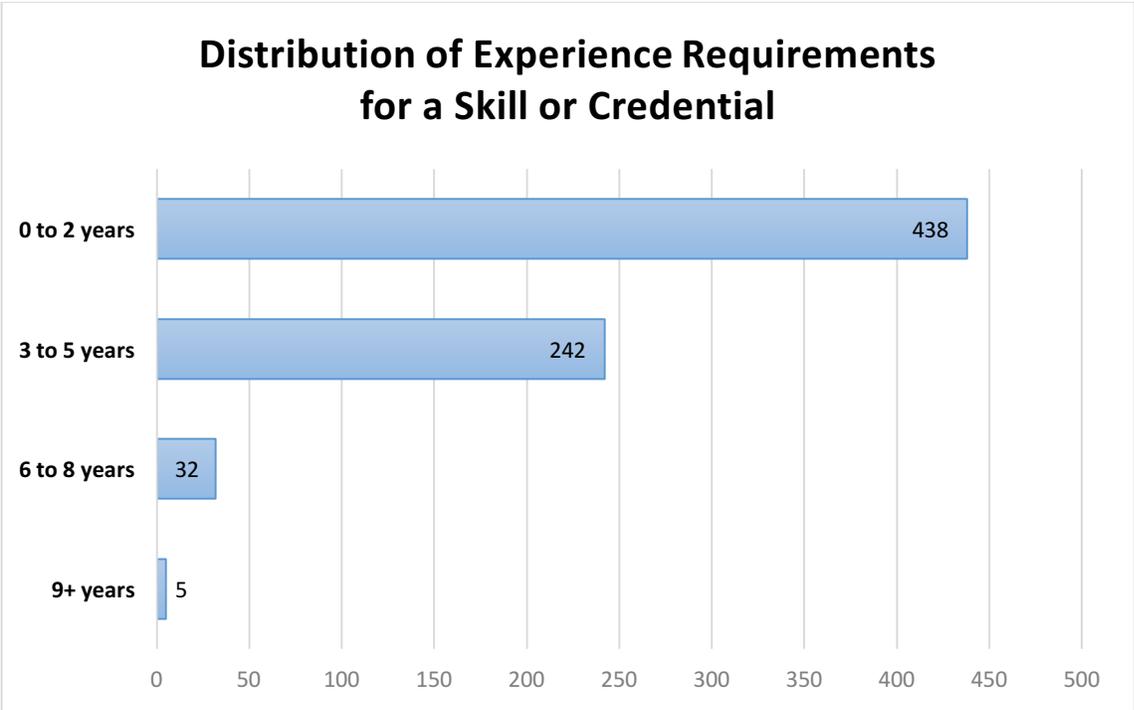
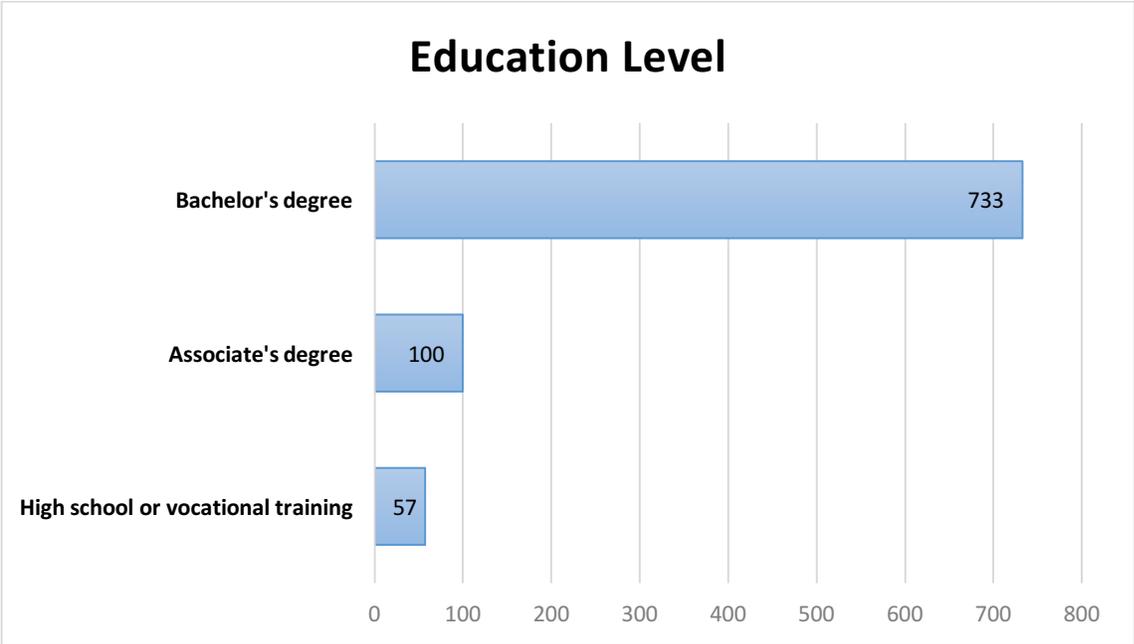
For California, the first six months of 2021 showed strong job posting activity from cell and gene therapy (CGT) companies. During the period, there were 1,217 job postings from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles. If the trend for the first six months continued through the second half of the year, then the projected annualized number for California would be 2,434 job postings, **which would be a 28% increase** compared to the 1,900 job postings in 2020.

Findings from 2020 Job Postings Data in San Francisco Bay Region

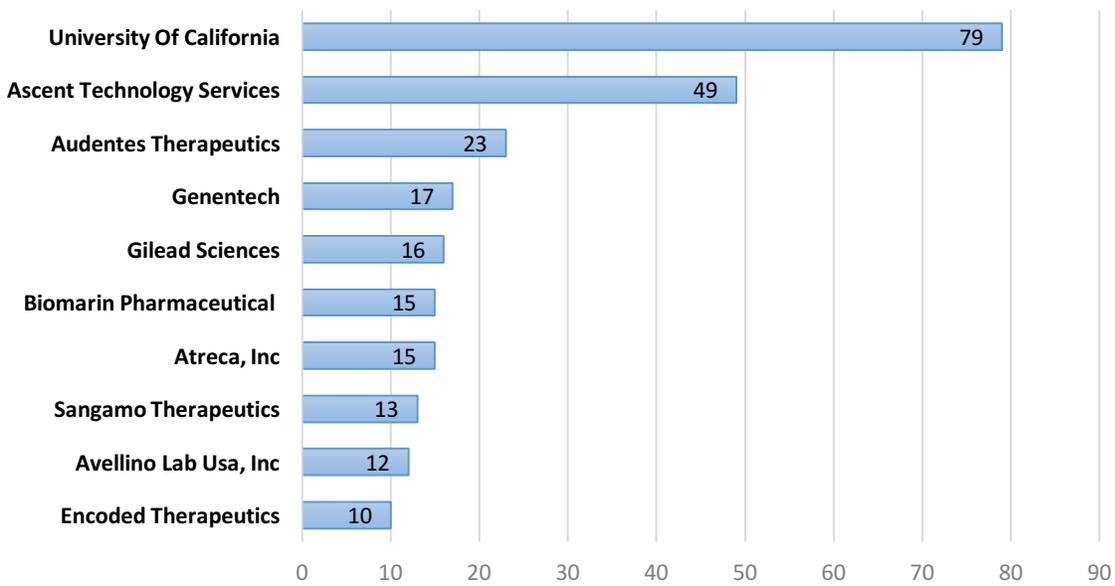
The following section displays job postings data related to demand for cell and gene therapy technicians in the San Francisco Bay Region for calendar year 2020. **There were 894 job postings in the San Francisco Bay Region in 2020** from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles.

The data is from Burning Glass/Labor Insight and covers the following information:

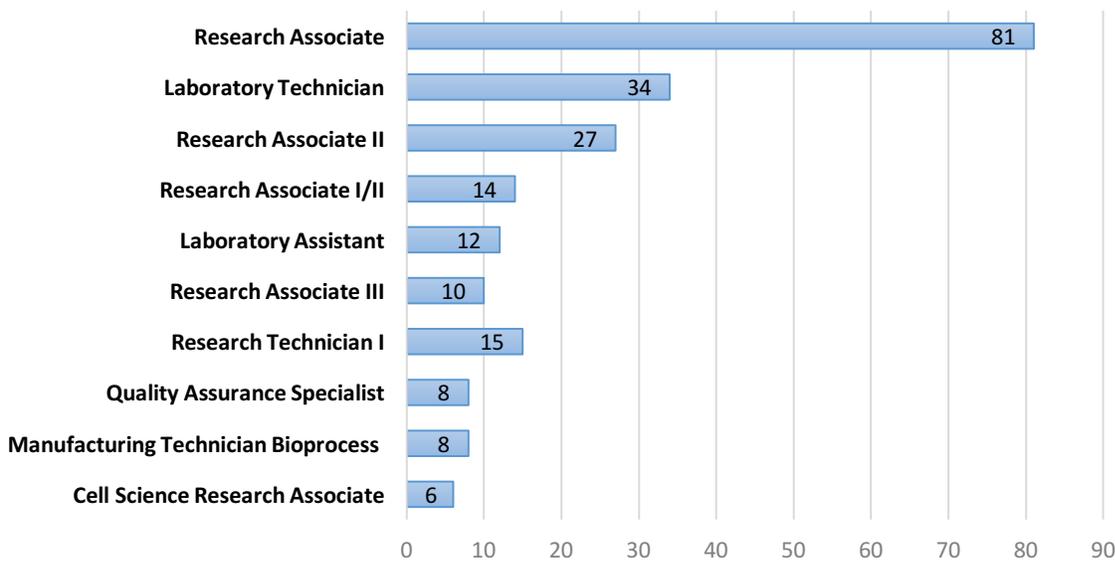
- Education level and experience employers are seeking
- Top employers in the state with most job postings
- Top job titles posted by cell and gene-therapy companies
- Top specialized skills and baseline/workplace skills most in demand by employers
- Trend line for these positions by region looking back 10 years



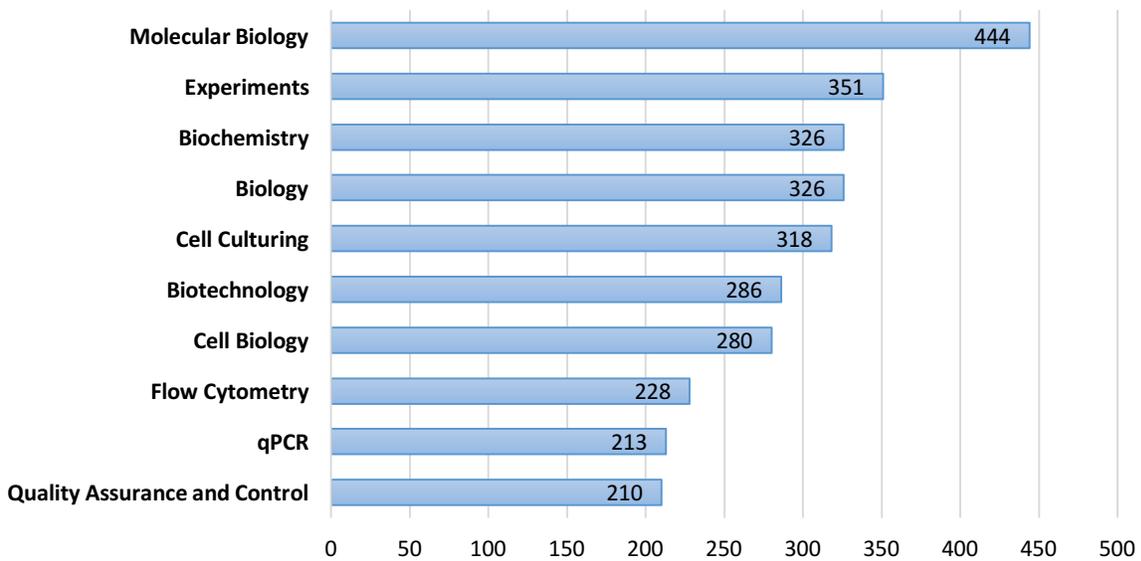
Top Employers



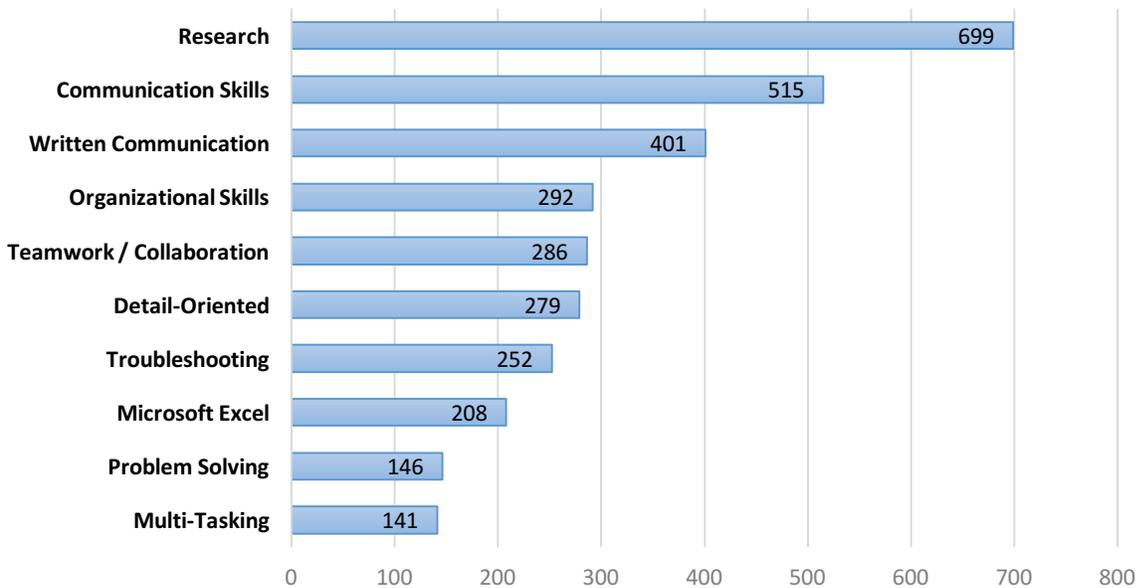
Top Job Titles

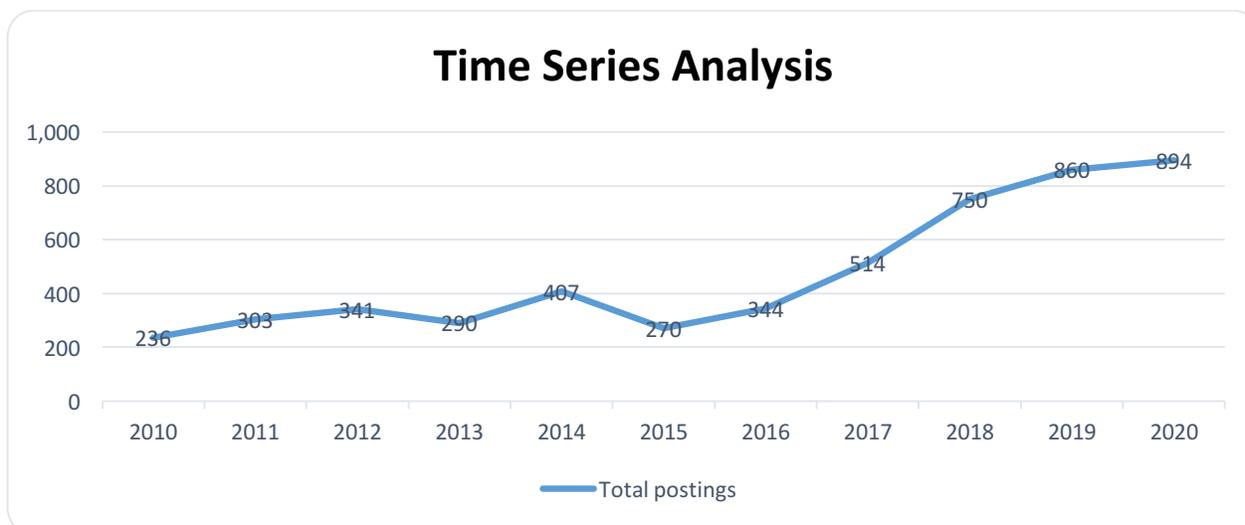


Top Specialized Skills



Top Baseline Skills





Job Postings for January - June 2021

For the San Francisco Bay Region, the first six months of 2021 showed strong job posting activity from cell and gene therapy (CGT) companies. During the period, there were 556 job postings from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles. If the trend for the first six months continued through the second half of the year, then the projected annualized number for the region would be 1,112 job postings, **which would be a 24% increase** compared to the 894 job postings in 2020.

San Diego Region

Growth and Economic Impact of Cell and Gene Therapy Companies

San Diego ranked #5 in the Top 10 U.S. Biopharma Clusters in 2020

Maravai Life Sciences grossed \$1.86 billion when it went public in 2020, capping a year that saw the company and its TriLink Biotechnologies [move to expanded space within San Diego](#), with TriLink completing its cGMP space in January. MilliporeSigma revealed plans for a \$110 million second viral vector facility in Carlsbad, CA.

San Diego ranked third in Venture Capital (third with \$4.794 billion in 2019 and 2020), ranked fourth in patents (5,973), thanks to its strong base of universities led by University of California, San Diego, and numerous research institutions. San Diego ranked sixth in lab space (23.3 million square feet), ranked 10th in NIH funding (2,118 awards totaling \$1.162 billion) and ranked seventh in jobs (with 68,000

according to statewide life sciences industry group Biocom). (Source: “Top 10 U.S. Biopharma Clusters”, *genengnews.com*, 2020)

Generations of serial entrepreneurs

The presence of researchers capable of launching and growing successful businesses has made the San Diego region a leader in life sciences, stretching back to the creation of the region’s first biotech company, Hybritech, in 1978. “I think sometimes people don’t realize that when companies like Genentech were being formed [in San Francisco], and companies like Biogen were being formed in the Boston area, that Hybritech was being formed here,” says Joseph Panetta, president and CEO of Biocom, a San Diego-based group promoting life sciences activity across California.

“We’ve got that depth of experience of serial entrepreneurs, many, many of whom are still very, very much active in the industry here today,” Panetta continues. “Yet that early group of serial entrepreneurs has now handed the reins to the second or third generation of entrepreneurs following them, so that depth of serial entrepreneurial experience goes way, way back—about 40 years.”

Hybritech went public in 1981, and five years later was acquired by Eli Lilly for \$480 million. Eli Lilly remains among the biopharma anchors in San Diego, and in 2020 the company partnered with Menlo Park, CA-based Strateos to complete the 11,500-square-foot Lilly Life Sciences Studio. The companies built a robotic laboratory that is designed to accelerate drug discovery within Lilly’s San Diego Biotechnology Center, where the pharma giant completed a \$90 million expansion in 2017.

Another biopharma giant in San Diego is Takeda Pharmaceutical, which last year opened a 165,000-square-foot Global Research Center where 250 employees apply specialized drug discovery technologies and advance discovery research in gastroenterology and neuroscience.

“We’ve got the geographic density, with 90% of our biotech being located within a radius of about five miles or so from the Sorrento Mesa/Sorrento Valley area stretching up to Del Mar and out to La Jolla, and across to the Mesa as well,” Panetta points out. “In San Diego, we’ve got a uniqueness in that our research centers and Morris Cancer Center at the University of California, San Diego, along with the private research institutes—the Salk Institute for Biological Studies, the Scripps Research Institute, Sanford Burnham Prebys Medical Discovery Institute (SBP), and the La Jolla Institute for Allergy and Immunology—are all within very, very close proximity to each other.”

The institutions partner with each other, with one example being the Sanford Consortium for Regenerative Medicine, where UCSD, La Jolla, Salk, SBP, and Scripps, pursue collaborative research. The Sanford Consortium operates from a research facility funded in part with a \$43 million grant from the California Institute for Regenerative Medicine, the state's stem cell agency on whose board Panetta serves, and a \$30 million donation from philanthropist T. Denny Sanford of South Dakota, for whom the Sanford Consortium was renamed. (Source: "In Praise of Lesser-Sung Life Sciences Clusters", *genengnews.com*, 6/25/20).

Kite Pharma, a subsidiary of Gilead Company, announced plans to build a new viral vector manufacturing facility in Oceanside, California, US, in July 2019. The facility will be used for manufacturing viral vectors for production of cell therapy as well as the company's first commercially available chimeric antigen receptor T (CAR T) cell therapy known as Yescarta[®]. The new facility will improve development, manufacturing, and supply capabilities of the existing CAR T-cell therapies and future pipeline products.

(Source: "Kite Pharma's Viral Vector Manufacturing Facility, California", www.pharmaceutical-technology.com, 2021)

Open Biopharma

Open Biopharma operates a "future biopharma manufacturing facility" (FutureFacility™) located in Carlsbad, CA which is strategically placed in the heart of the Southern California biotech cluster. Their goal is to drive innovation that reduces the cost of biopharma manufacturing and as an educational institution to ensure the training of life sciences professionals for the newest biopharmaceutical manufacturing and related technologies. More than forty percent of upcoming therapeutics in their respective R&D pipelines are biopharmaceuticals and the industry has a critical shortage of trained process development and biomanufacturing personnel to meet this need.

Open Biopharma uses a ballroom design to create a truly dynamic space called the Sandbox. The Sandbox holds a variety of the latest equipment and technology platforms; including single use, continuous, integrated, and automation from different vendors across the industry. The Sandbox concept allows biopharmaceutical companies, vendors, and regulators to evaluate the impact of these new technologies on the biopharmaceutical processes and facilitate the adaptation of these progressive technologies into industry best practices. In addition, they focus on enhancing industry through current best practices and future-facing training which helps drive innovation and regional development as well.

(Source: <https://www.openbiopharma.org/#about>)

Labor Market for Cell and Gene Therapy Workforce

The following workforce section will be organized in two parts: 1) findings from a “literature review” of existing workforce research, reports and articles documenting the demand for biomanufacturing technicians with cell and gene therapy (CGT) knowledge and skills and 2) findings from job postings data related to the demand for CGT technicians which will include data on numbers of job postings, top employers, top job titles, skills in demand, and education and experience desired by employers.

San Diego Life Sciences Employment

Millions of people around the world look to California life sciences companies for hope in the fight against their diseases and illnesses affecting a loved one. In 2019, California companies had 1,380 new medicines in the pipeline. These included 455 medicines for cancer, 136 for central nervous system (CNS) disorders and 105 for infectious diseases. In addition, in 2019, California companies received 18 expedited approvals from the FDA, accelerating the industry’s ability to get new treatments to patients in critical need. In 2018 there were 323,723 life science employees in California, a 4% increase over the previous year. 46,709 of these employees (14%) worked in the biopharmaceuticals sector.

(Source: *California Life Sciences Sector Report 2020, California Life Sciences Association (CLSA)*).

San Diego County’s Life Sciences industry provided more than 68,000 jobs in 2019 with average annual earnings exceeding \$130,000 per year. There was solid job growth in Biopharmaceuticals, Medical Devices and Research & Lab Services support between 2014 and 2019. Total Life Sciences exports from San Diego County totaled more than \$24 billion in 2019 and institutions and companies received over \$1 billion in new research awards from the National Institutes for Health in 2019. The economic impacts of the Life Sciences industry in San Diego include:

- Generates \$41.3 billion in county economic activity (output)
- Adds \$23.8 billion to gross regional product
- Supports 175,000 jobs
- Increases labor income in the county by \$14.1 billion per year

(Source: *2020 California Economic Impact Report: Data Book, BioCom*)

The biopharmaceutical sector is part of the thriving life sciences sector with 119 companies and over 7,500 biopharmaceutical jobs in San Diego County. Biopharmaceutical manufacturing jobs represent

11% of all life science jobs in San Diego County and employment is projected to increase from 7,565 workers in 2019 to 8,118 workers by 2024, a 7.3% increase over the period. (Source: California Life Sciences Association, 2019 and 2020 California Economic Impact Report: Data Book, BioCom).

Carlsbad based biotech company MilliporeSigma is outgrowing its current facility and is now building an additional site just a couple of miles away, **making space for another 100 new workers**. "There is such an enormous amount of potential for transforming medicine and transforming lives," says Joan Haab, the company's site lead. **MilliporeSigma manufactures viral vectors for the cell and gene therapy market**. It's one of an estimated 1,200 biotech businesses in the county, which continue to add jobs amid the coronavirus outbreak.

In 2020, 37,400 San Diegans worked in the field, up 5.4% from a year earlier. MilliporeSigma will need employees qualified to help build its products and the company wants to recruit out of San Diego. "You don't walk on the job, gown up and go in," says Haab. "There is a lot of training involved." Haab made special mention of **MiraCosta College's biotech program as a place that teaches students the skills needed to break in**.

Department Chair Barbara Juncosa says students can earn a certificate in one semester, or stay for four years and earn a Bachelor's degree - without getting saddled with a tremendous amount of debt. "It's a time of a lot of opportunity for individuals who are looking to retool and find a new path if they find themselves out of work," said Juncosa. (Source: "San Diegans can quickly retrain for biotech jobs in demand", ABC News San Diego, www.10News.com).

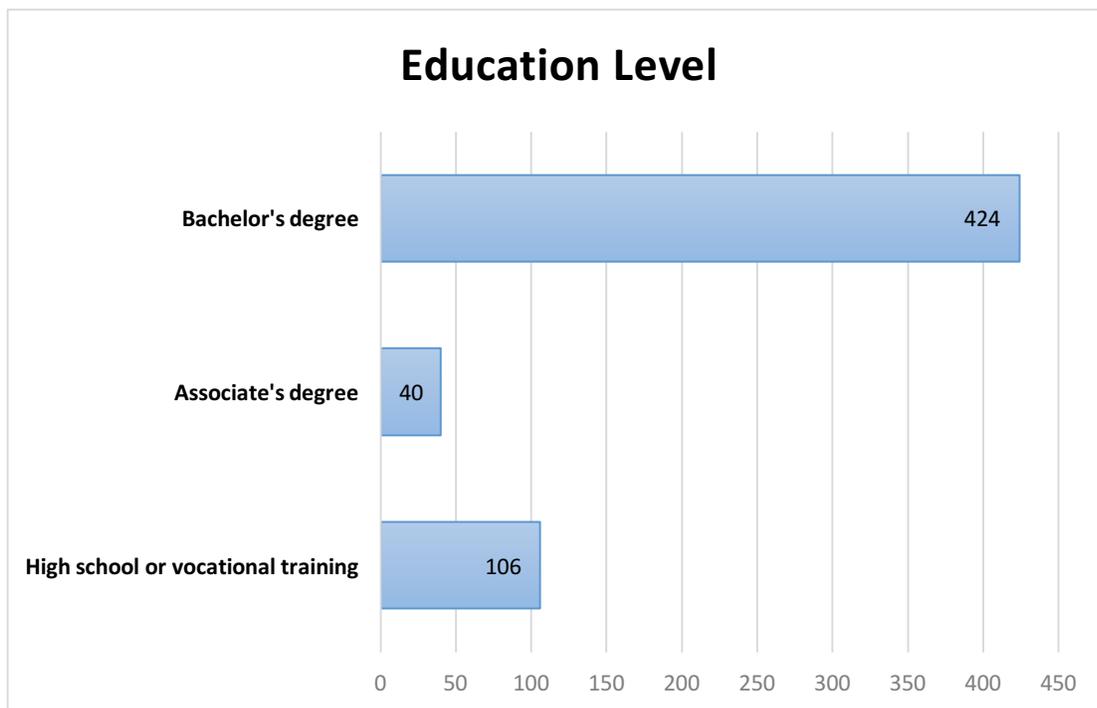
In 2021, Thermo Fisher Scientific will be expanding their 8,000+ employee footprint in California with the opening of a new site in Carlsbad, CA. The new facility will expand clinical and commercial capabilities for plasmid DNA – used as a critical raw material to develop and manufacture cell and gene-based therapies, including life-saving cancer treatments, as well as mRNA vaccines. The new site will also increase COVID-19 vaccine manufacturing capacity. (Source: Press Release from Thermo Fisher Scientific, "Thermo Fisher Expands Clinical and Commercial Capabilities for Plasmid DNA Manufacturing", December 2020).

Findings from Job Postings Data in San Diego region

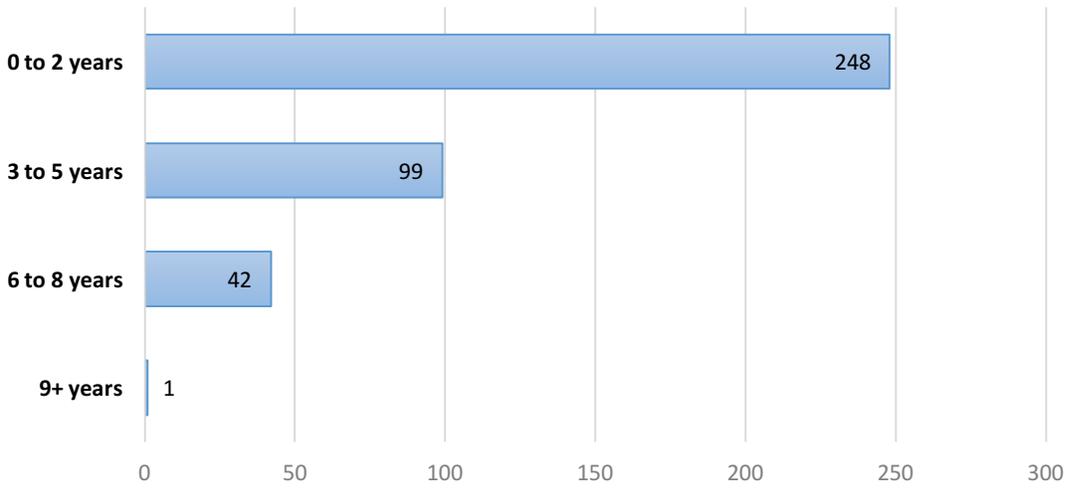
The following section displays job postings data related to demand for cell and gene therapy technicians in California for calendar year 2020. **There were 570 job postings in the San Diego region in 2020** from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles.

The data is from Burning Glass/Labor Insight and covers the following information:

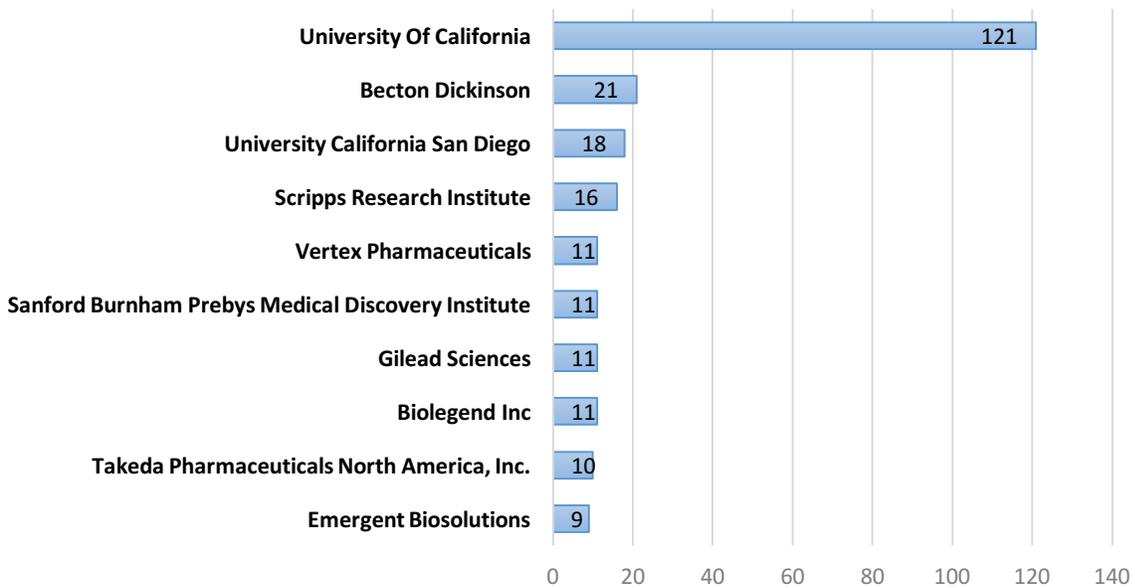
- Education level and experience employers are seeking
- Top employers in the state with most job postings
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- Top specialized skills and baseline/workplace skills most in demand by employers
- Trend line for these positions by region looking back 10 years



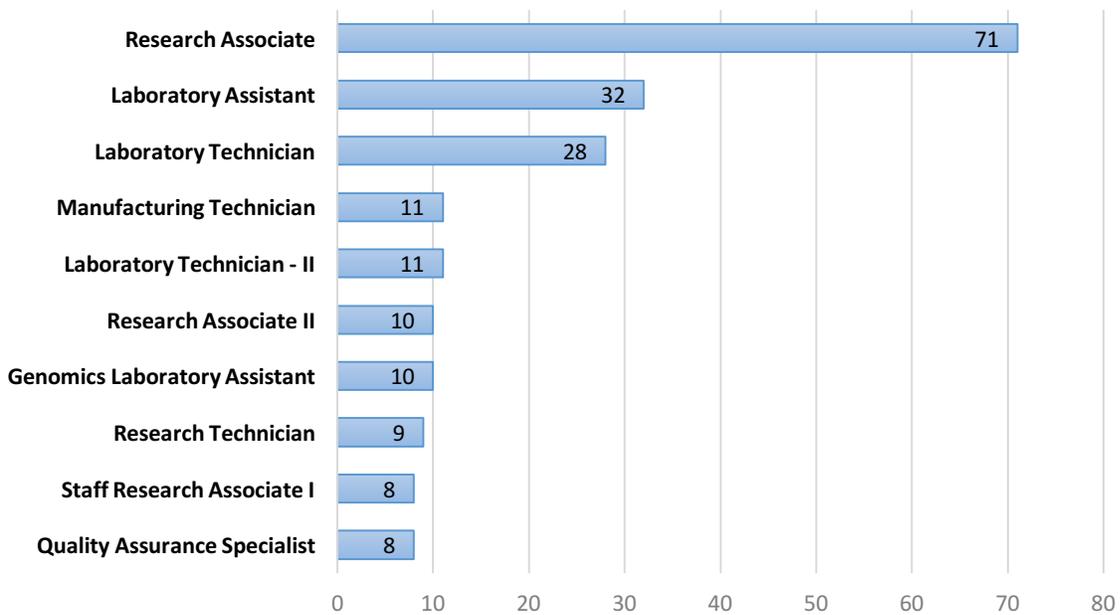
Distribution of Experience Requirements for a Skill or Credential



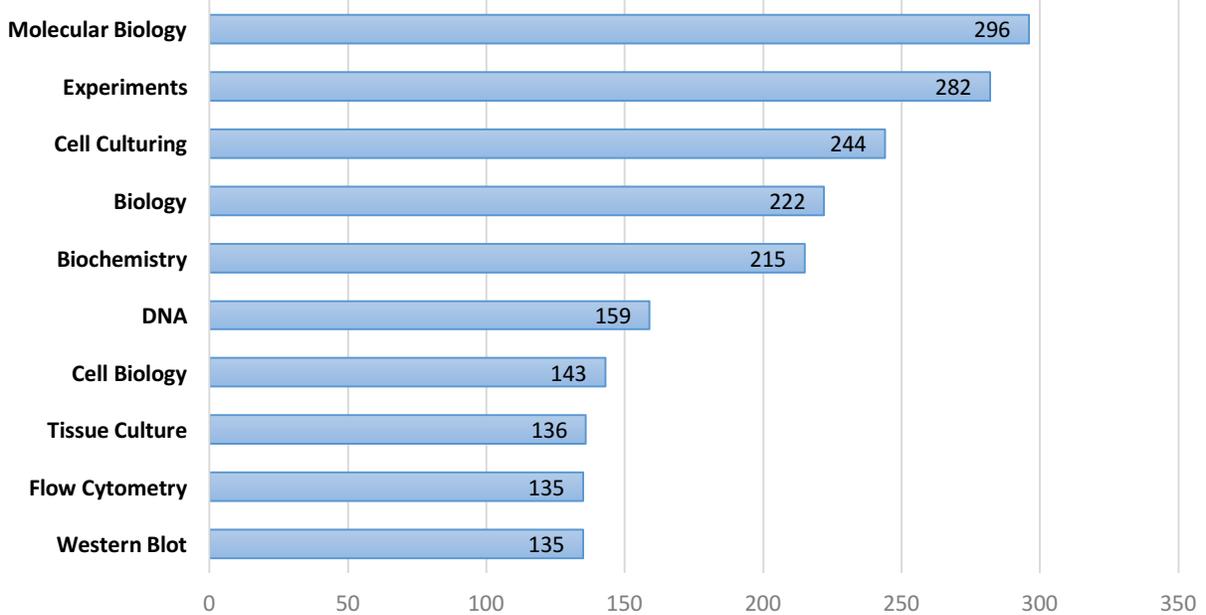
Top Employers

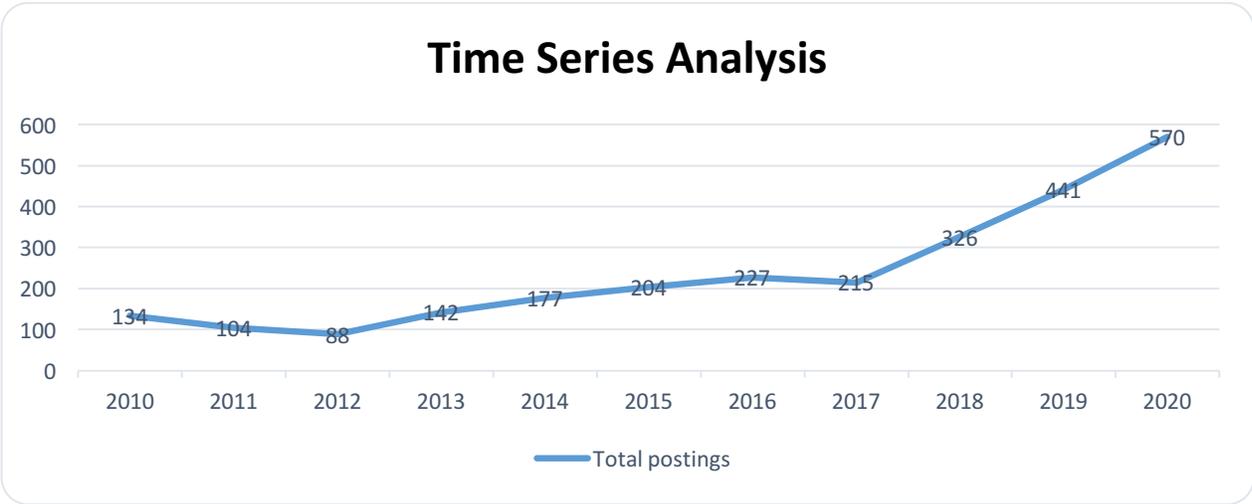
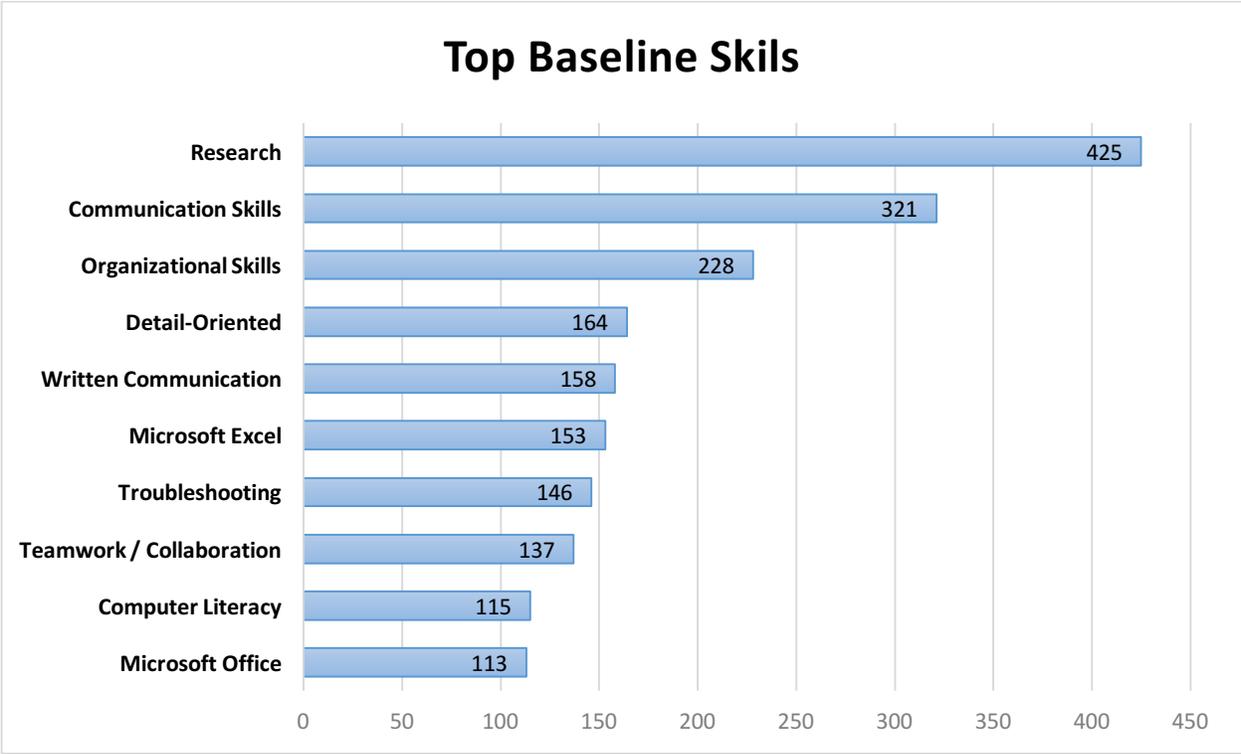


Top Job Titles



Top Specialized Skills





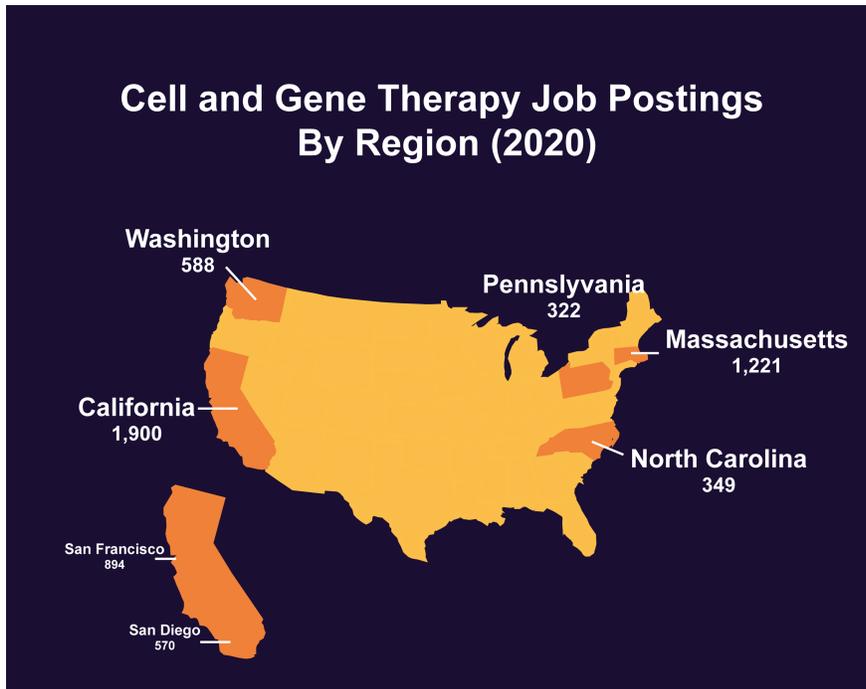
Job Postings for January - June 2021

For the San Diego region, the first six months of 2021 showed strong job posting activity from cell and gene therapy (CGT) companies. During the period, there were 339 job postings from cell and gene therapy companies that employ technicians with cell and gene therapy related job titles. If the trend for the first six months continued through the second half of the year, then the projected annualized

number for the region would be 678 job postings, **which would be a 19% increase** compared to the 570 job postings in 2020.

Cell and Gene Therapy Job Postings in U.S. By Region

The graphic below shows the total number of job postings in calendar year 2020 for each of the six regions highlighted in this report.



Up and Coming: Six Emerging Regions for Cell and Gene Therapy

BIOHEALTH CAPITAL REGION

The Maryland/Virginia/Washington, DC BioHealth Capital Region (BHCR) has promoted, and seen, growing collaboration between its anchors in government, academia, and industry—especially in the months since COVID-19 began wreaking havoc upon the world.

They include U.S. National Institutes of Health (NIH), which bases most of its 19,000 employees (including some 6,000 researchers) at its Bethesda headquarters, as well as staffers at the NIH’s National Institute of Allergy and Infectious Diseases. The BHCR region’s anchors also include the U.S. Food and Drug Administration (FDA), Johns Hopkins University (the top recipient of NIH grant funding last year according to *GEN*), and the Centers for Medicare and Medicaid Services.

BHCR has seen several companies expand such as London-based Autolus Therapeutics, a developer of chimeric antigen receptor (CAR) T-cell therapies for cancer, with planned construction and development of an approximately 85,000-square-foot office/manufacturing facility at the Shady Grove Life Sciences Center in Rockville, MD. And Aurinia Pharmaceuticals, a Victoria, BC-based developer preparing for a

2021 launch of voclosporin, a drug for treating lupus nephritis, established a U.S. commercial center of operations in Rockville, MD.

(Source: "In Praise of Lesser-Sung Life Sciences Clusters", genengnews.com, 6/25/20).

MINNESOTA

Also benefiting from the presence of top-tier companies and institutions is Minnesota, where the Medical Alley Association is promoting an expansive vision of Minnesota as a global epicenter of innovation and care. The Mayo Clinic in Rochester, signaled its intent to pursue global leadership in digital health in December by appointing John Halamka, MD, as president of the Mayo Clinic Platform, a strategic initiative aimed at improving healthcare through insights and knowledge derived from clinical data.

St. Paul-headquartered 3M is active in areas ranging from biopharmaceutical purification to drug delivery systems, in addition to medical devices and healthcare information systems. Takeda last month wrapped up FDA preapproval inspection at its biologics plant in Brooklyn Park, MN, acquired from Baxalta in 2016. Minneapolis-based Bio-Techne will invest between \$40 million and \$50 million to expand its GMP-grade protein production capacity into St. Paul. Bio-Techne also joined Fresenius Kabi and Wilson Wolf to launch a joint venture aimed at providing dedicated support to researchers and biopharmaceutical companies in cell and gene therapy.

(Source: "In Praise of Lesser-Sung Life Sciences Clusters", genengnews.com, 6/25/20).

ATLANTA

The COVID-19 global pandemic brought global attention to the U.S. Centers for Disease Control and Prevention (CDC), reinforcing the agency's standing as the nation's leading public health institute—as well as its central role in Metro Atlanta's life sciences community. The CDC, has 9,000 employees followed by university life sciences departments with 8,600 employees and biopharma companies with 8,400 employees. Metro Atlanta's life sciences industry also includes a growing number of biopharma companies. Takeda operates a plasma fractionation manufacturing site in suburban Covington, which employs more than 1,000 full-time and contract employees.

(Source: "In Praise of Lesser-Sung Life Sciences Clusters", genengnews.com, 6/25/20).

METRO DENVER

Pfizer's \$11.4 billion acquisition of Boulder-based Array BioPharma provides the most telling example of how much biopharma and the life sciences have grown over the past decade in the northern Colorado region anchored by Denver, Boulder, and Aurora. The region's life sciences industry grew 7.5% between 2011 and 2017, surpassing the national life sciences growth rate of 5.4%, according to the Metro Denver Economic Development Corporation.

Two Boulder life sciences companies completed major financings last year: Clovis Oncology, which raised \$175 million in clinical trial financing and Inscripta, which completed a \$125 million Series D financing round, with proceeds set to fund commercialization of its Onyx™ Digital Genome Engineering platform. One of Metro Denver's newest biotech arrivals, AveXis, acted to expand its gene therapy manufacturing capacity by purchasing AstraZeneca's former advanced biologics therapy manufacturing campus in Longmont for \$30 million.

In 2019, AstraZeneca sold a second site in the region, a biologics bulk manufacturing plant in Boulder, to Bothell, WA-based CDMO AGC Biologics. AGC has promised to create 280 new jobs paying an average

annual wage of \$96,253—a total investment of \$100 million—in return for incentives from the Colorado Economic Development Commission. *(Source: “In Praise of Lesser-Sung Life Sciences Clusters”, genengnews.com, 6/25/20).*

CHICAGO

A life sciences cluster has also grown in recent years in and around Chicago, where three federal laboratories, several biopharma giants, and an emerging community of startups are buttressed by a strong base of academic research institutions—including Northwestern University, the University of Chicago, and the University of Illinois. Horizon Therapeutics plans to move its U.S. employees in the second half of this year from its Lake Forest site to a larger site, a three-building, 650,000-square-foot campus in Deerfield.

(Source: “In Praise of Lesser-Sung Life Sciences Clusters”, genengnews.com, 6/25/20).

NEW YORK METRO

Also enjoying a life sciences real estate boom is New York City, which has benefited from New York State’s \$620 million Life Science Initiative. The initiative includes \$100 million to expand the Excelsior Jobs Program of refundable tax credits; \$100 million for a new life sciences R&D tax credit; and \$320 million in state grants to support the development of wet-lab and innovation space, support operations, and investment capital for early-stage life sciences companies. The initiative also includes at least \$100 million in private sector investment.

“New York City sits directly at the heart of the Eastern U.S. life sciences corridor—which also includes Boston, Philadelphia, Maryland, and North Carolina—and is one of the world’s most concentrated locations for life sciences, technology, and healthcare,” says Nancy J. Kelley, a steering committee member of NYC Builds Bio+, which advances life sciences development in New York City by uniting the city’s real estate and life sciences communities. According to the privately funded economic development agency Choose New Jersey, the Garden State is home to more than 400 biotech companies, and 13 of the top 20 biopharmaceutical companies. Last year, New Jersey Governor Phil Murphy enacted a doubling of the state tax credit for angel investors in July.

(Source: “In Praise of Lesser-Sung Life Sciences Clusters”, genengnews.com, 6/25/20).

APPENDIX A: National Literature Review of Cell and Gene Therapy Reports and Articles

An extensive literature review was conducted to identify and review economic and workforce articles and reports on the growing cell and gene therapy sector. Over 80 articles and reports were compiled and reviewed, providing a robust collection of the most current information on this topic.

Title of Report/Article	Date	Source	Geography
Window on the Workplace 2020: Workforce Training Needs for North Carolina's Biopharma Manufacturing Industry	2020	North Carolina Biotechnology Center; The NCBIO Biosciences Organization	North Carolina
Cell and Gene Therapy and Connected Health Workforce Analysis	2020	CEO Council for Growth; University City Science Center; University City District's West Philadelphia Skills Initiative; Econsult Solutions, Inc.	Philadelphia
Trendline: Gene Therapy		BioPharma Dive; Bio Rad	National
Covid-19 Vaccines Are in High Demand, but Thousands More Workers Are Needed to Make Them	2021	Wall Street Journal	National
9 Philly Companies on the Cutting Edge of Cell and Gene Therapy Innovation	2020	Philadelphia Magazine	Philadelphia
Bristol Myers finally wins FDA approval for cancer cell therapy	2021	BioPharma Dive	National
Boston's in a lab-building boom. What will that mean for the city and its neighborhoods?	2021	Boston Globe	Boston
The California Life Sciences Industry: San Diego County	2019	California Life Sciences Association	San Diego
The California Life Sciences Industry: San Francisco	2019	California Life Sciences Association	SF Bay
Leading Life Science Clusters: The Bio-Boom Intensifies	2020	CBRE Research	National
2020 California Economic Impact Report: Data Book	2020	Biocom	California
California Life Sciences Sector Report	2020	California Life Sciences Association; PricewaterhouseCoopers	California
The Bioscience Economy: Propelling Life-Saving Treatments, Supporting State & Local Communities	2020	TEconomy Partners; Biotechnology Innovation Organization	National
UK cell and gene therapy skills demand report 2019	2019	Catapult Cell and Gene Therapy	International (UK)
Cell and gene therapy GMP manufacturing in the UK: Capability and capacity analysis	2020	Catapult Cell and Gene Therapy	International (UK)
LinkedIn lowdown: Without staff, what good is manufacturing space?	2021	BioProcess International	International (UK)
Cellular & Gene Therapy Products	2021	Food and Drug Administration (FDA)	National
Approved Cellular and Gene Therapy Products	2021	Food and Drug Administration (FDA)	National
Life Sciences 2030 Skills Strategy	2020	Science Industry Partnership	International (UK)
Innovation in the Time of COVID-19 ARM Global Regenerative Medicine & Advanced Therapy Sector Report	2020	Alliance for Regenerative Medicine	International
Gene Therapy	2021	Mayo Clinic	National
The Dynamics of California's Biotechnology Industry	2005	Public Policy Institute of California (PPIC)	California
Supply and Demand Analysis : Life Sciences & Biotech Middle Skills Workforce in California	2017	California Community Colleges Center of Excellence for Labor Market Research	California
Cell and Gene and Cell Therapy FAQs	2021	American Society of Cell and Gene Therapy	National
UC Davis Gene Therapy Center	2020	UC Davis	California
Making the Move: Bringing Cell and Gene Therapy Development Programs to the United States	2018	IQVIA	National
Cell and Gene Therapy Center	2021	California Institute for Regenerative Medicine	California
Cell and Gene Therapies: A Manufacturing View	2019	DCAT Value Chain Insights	National
Orchard Therapeutics Announces the Build-out of New Gene Therapy Manufacturing Facility in California	2018	BBC Newswire	California

California Life Sciences Industry Report 2019	2019	California Life Sciences Association (CLSA) and PricewaterhouseCoopers (PwC)	California
Understanding and Explaining Viral Vector COVID-19 Vaccines	2021	Centers for Disease Control and Prevention (CDC)	National
Merck KGaA, Darmstadt, Germany Announces Boost to Commercial Viral Vector and Gene Therapy Manufacturing Capacity	2020	Merck KGaA	California
Biopharmaceutical Manufacturing in the U.S.: Making Cutting-Edge Medicines Today and Leading the Way on Medicines of Tomorrow	2019	TEconomy Partners	National
Investment, Innovation and Job Creation in a Growing U.S. Bioscience Industry	2018	TEconomy Partners	National
Advanced Biopharmaceutical Manufacturing: An Evolution Underway	2015	Deloitte	National
Bayer to Invest \$150 Million in New Cell Manufacturing Plant in Berkeley	2019	BioSpace	California
bluebird bio to Cut Ribbon on New Gene Therapy Factory in Durham, NC; Plans to Hire	2019	BioSpace	North Carolina
Rapid growth in biopharma: Challenges and opportunities	2014	McKinsey and Company	International
Viral Vectors and Plasmid DNA Manufacturing Market (2nd Edition), 2018-2030	2018	Roots Analysis	International
Sarepta Therapeutics Enters into Long-term Strategic Manufacturing Partnership with Brammer Bio to Support Gene Therapy Development and Commercial Supply	2018	Sarepta Therapeutics	National
Novartis-owned AveXis bringing \$55M gene therapy factory, 200 jobs to Durham	2018	WRAL TechWire	North Carolina
Pharma operations: Creating the workforce of the future	2020	McKinsey and Company	National
Enhancing Today's STEM Workforce to Ensure Tomorrow's New Medicines: Biopharmaceutical Industry Partnerships with U.S. Colleges and Universities	2017	TEconomy Partners	National
2018 LIFE SCIENCE WORKFORCE TRENDS REPORT	2018	Coalition of the State Bioscience Institutes	California
Medicines in Development: Biologics	2013	PHRMA (Pharmaceutical Research and Manufacturers of America)	National
Much in Demand: In conversation with Stephen Ward, Chief Manufacturing Officer at the UK's Cell and Gene Therapy Catapult	2020	The Medicine Maker (Interview with Catapult Executive)	International (UK)
Skills Shortage: Could the Pharmaceutical Industry Be in Trouble?	2019	Lab Manager	National
Closing the Biopharma Skills Gap	2020	European Pharmaceutical Manufacturer (Interview with Professor from Biopharma Education Center)	International (Switzerland)
The Rise Of Gene & Cell Therapy And The Resulting Need For In-House Production Facilities: A Guide;	2020	Cell and Gene.com (Life Science Connect)	National
Philadelphia's Talent Pipeline Collaborative Readies Region For Cell And Gene Therapy Job Growth;	2021	Cell and Gene.com (Life Science Connect)	Philadelphia
The Center for Breakthrough Medicines Is Building the World's Largest Cell and Gene Therapy CDMO To Launch In King Of Prussia, PA	2020	Cell and Gene.com (Life Science Connect)	Philadelphia
The Emergence of New Gene Therapy Hubs	2018	Cell and Gene.com (Life Science Connect)	National
Philadelphia: The Cell and Gene Therapy Sector's New Normal	2019	Cell and Gene.com (Life Science Connect)	Philadelphia
Cell and Gene Therapy Bioprocessing: Hiring And Capacity Crunch On The Horizon	2020	Cell and Gene.com (Life Science Connect)	National
Vibalogics Initiates \$150M Virotherapy Manufacturing Facility Expansion In Greater Boston	2021	Cell and Gene.com (Life Science Connect)	Boston
Mass BIO: State of Possible 2025 Report	2020	Mass BIO	Boston
Hiring During a Biotech Boom: The Talent Challenges	2020	BioBuzz.io	National

Facing Companies Across All Markets			
Top 10 U.S. Biopharma Clusters	2019	sciencecenter.org	Seattle & National
Project Farma: Manufacturing Skills Gap Creates Bottleneck for Cell and Gene Therapy	2021	biospace.com	National
In Praise of Lesser-Sung Life Sciences Clusters	2020	genengnews.com	Seattle, NC, San Diego
Alliance for Regenerative Medicine 2020 Annual Report: Growth & Resilience in Regenerative Medicine	2020	Alliance for Regenerative Medicine	National
Alliance for Regenerative Medicine 2021 State of the Industry Presentation Slides	2021	Alliance for Regenerative Medicine	National
Mapping Cell and Gene Therapy Processes	2021	Cell and Gene.com (Life Science Connect)	National
2020 global life sciences outlook	2020	Deloitte Insights	National
Tech will drive change in health care throughout next decade	2019	Puget Sound Business Journal	Seattle
Mining Talent in Cell and Gene Therapy Manufacturing	2019	BLS Strategies, blsstrategies.com	National
San Diegans can quickly retrain for biotech jobs in demand	2020	ABC news, 10news.com	San Diego
FujiFilm facility will bring 725 “good paying” jobs to Holly Springs	2021	ABC news, abc11.com	North Carolina
Largest Biotechnology Companies	2019	Puget Sound Business Journal	Seattle
Largest Biopharma Companies in the Greater Bay Area	2020	SF Business Times	Bay Area
Pharma Manufacturing is a growing career path...	2021	www.wraltechwire.com	North Carolina
Why Philadelphia is Poised to Become a Top CGT Cluster	2021	BioBuzz.io	Philadelphia
Solving the Talent Crisis in Gene Therapy	2021	rlc.randstadusa.com	National
Brandywine Realty Trust and Pennsylvania Biotechnology Center Partner on Life Science Incubator within 14-acre \$3.5 billion Schuylkill Yards Innovation Neighborhood	2021	bussinesswire.com	Philadelphia
Kite Pharma’s Viral Vector Manufacturing Facility, California	2021	www.pharmaceutical-technology.com	San Diego
Bristol-Myers Squibb’s New Cell Therapy Manufacturing Facility, Devens, Massachusetts	2021	www.pharmaceutical-technology.com	Boston
About Open Biopharma	2021	https://www.openbiopharma.org/#about	San Diego
Supporting the Rise of Biomanufacturing in Massachusetts will Ensure the Sustainability of the State of Possible	2021	www.MassBIO.org.news	Boston
Top 10 Life Sciences Jobs Most in Demand Over the Next Decade	2020	genengnews.com	Boston
Biotech businesses choosing Quincy	2019	The Patriot Ledger	Boston

APPENDIX B: Methodology for Determining Job Postings Data for Cell and Gene Therapy Companies in Six Regional Hubs

The following selection criteria were used to identify job postings from cell and gene companies who were hiring for biomanufacturing technicians with cell and gene therapy knowledge and skills. The job postings data is from Burning Glass Technologies.

- 1. Calendar year 2020**
- 2. Education level of Bachelors degree or less**
- 3. Six Middle Skills Biotech Occupations narrowed the occupations**
 - Biological Technicians
 - Chemical Technicians
 - Manufacturing Production Technicians
 - Quality Control Analysts
 - Medical and Clinical Laboratory Technicians
 - Inspectors, Testers, Sorters, Samplers and Weighers
- 4. 12 Key Words identified the cell and gene jobs and companies**
 - cell therapy
 - gene therapy
 - genetics
 - cell biology
 - immunotherapy
 - regenerative medicine
 - stem cells
 - viral vector
 - T-Cell therapies
 - Advanced therapy
 - Mammalian cell culture
 - Mammalian tissue culture
- 5. 12 NAICS Codes also identified the cell and gene companies**
 - Scientific Research and Development Services (5417)
 - Colleges, Universities, and Professional Schools (6113)
 - Pharmaceutical and Medicine Manufacturing (3254)
 - General Medical and Surgical Hospitals (6221)
 - Employment Services (5613)
 - Management, Scientific, and Technical Consulting Services (5416)
 - Medical and Diagnostic Laboratories (6215)
 - Administration of Human Resource Programs (9231)
 - Medical Equipment and Supplies Manufacturing (3391)
 - Navigational, Measuring, Electromedical, and Control Instruments Manufacturing (3345)
 - Other Professional, Scientific, and Technical Services (5419)
 - Specialty (except Psychiatric and Substance Abuse) Hospitals (6223)

Refinement Step 1: Excluding companies because job titles are for hospitals/healthcare organizations/other.

After reviewing an initial data pull of job postings for their state/region from Burning Glass, based on the criteria established by the project team, each hub lead identified companies to exclude from the data pull based on the job titles of certain companies not being typical for cell and gene therapy companies. Using these list of “excluded companies” a revised data pull of job postings was completed.

Example from California. The following 21 Companies were excluded for the reasons stated above.

- St Joseph Health System
- Covenant Health
- The Nielsen Company
- Saint Johns Health Center
- Oakvet Animal Specialty Hospital
- Brightspring Health Services
- Counseling4Kids
- Steep Hill Labs (Cannabis)
- Allan Hancock College
- Automotive Resources International
- Beyond Meat
- Dignity Health
- Sonic Healthcare Usa, Inc.
- Sunrise Medical Laboratories
- American Esoteric Laboratories
- BioReference Laboratories
- Clinical Laboratories Hawaii
- Westpac Labs, Inc.
- Cblpath, Inc.
- Clinical Pathology Laboratories. Inc.
- Mission Hospitals

Refinement Step 2: Additional Companies provided by Regional Hubs

The final step taken to identify all relevant job postings for each state/region was to request that each hub lead identify any known Cell and Gene Therapy (CGT) companies that were missing from the final list of job postings data for their state/region.

This list of “missing” companies were then used to search for relevant job postings that met the NAICS (industry code) criteria and the “six middle skills biotech occupations” criteria, so that only job postings for cell and gene therapy technicians as defined by the project team were identified for data pull #2 for each region. These new job posting and their associated data were then added to the job postings data from data pull #1 for a combined total for each region.

Bay Area Example

A list of 37 “Additional Bay Area Cell and Gene Therapy Companies” was generated by the Bay Area hub lead.

- Of the 37 employers “Additional Companies” that were not captured from Pull #1:
 - o 16 employers had online job postings for 2020 in California
 - o 14 employers had zero online job postings
 - o 7 employers did not exist in the Burning Glass database
- 15 employers remained after the NAICS code (industry code) filters were applied
- 1 employer remained after the NAICS code and SOC code (6 middle skills occupations) filters were applied.