

Life Sciences Assessment and Strategic Growth Opportunities for the Pittsburgh Region



Prepared for: Pittsburgh Life Sciences Alliance (PLSA)
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Prologue

Dear Readers and Regional Stakeholders,

Pittsburgh's life sciences ecosystem is poised at the intersection of the emerging data capabilities, technological applications, and clinical discoveries that will shape the next several decades of human health innovation. Many independent entities consistently rank our region among the world's top 20 emerging life sciences clusters. This presents a generational opportunity to expand our region's economy. But it is hardly a *fait accompli*.

Pittsburgh Life Sciences Alliance (PLSA) launched earlier this year by our board, composed of regional pillars of the economy and civil society, to connect our unique clinical, research, manufacturing, and technology strengths to enable the region as a global life sciences leader and economic engine.

To advance that ambitious charter, we must start by understanding the "ground truth" — the strengths and opportunities of the ecosystem today. We engaged TEconomy Partners, LLC (TEconomy), an independent outside expert, to conduct a thorough quantitative and qualitative analysis of the life sciences ecosystem in the region.

Two core questions guided us:

1. Where do we truly excel as a region in a way that is differentiated from other clusters in the United States and globally?
2. What are the structural challenges that are hindering our ascent from an emerging life sciences cluster to a true global heavy weight?

Over the past several months, TEconomy reviewed thousands of data sources to both enumerate our regional strengths and benchmark the region against near and aspirational peers. The research phase also included focus groups, workshops, and individual interviews with over 100 regional life science stakeholders from industry, academia, health care, government, and non-profit organizations. I personally feel a debt of gratitude to our Strategic Advisory Committee, Industry Advisory Committee, board of directors, and community members who provided considerable time, deep thought, and commitment to this process.

The results add fuel to our burning sense of optimism and confirm the upward trajectory of the sector locally. Some highlights include:

- Local researchers published over 100,000 articles from 2018-2022 in fields such as oncology, bioinformatics, and multiple surgical specialties.
- The velocity of VC deals in the industry is increasing. Since 2018, the number of deals has grown by 70 percent and the amount invested has more than tripled – both far outpacing state and national growth rates.
- In 2023, the Pittsburgh region's life sciences industry accounted for \$3.4 billion in economic output and more than 15,500 jobs.

The most strategically important finding of this work is that as a region, we have two distinct but complementary "growth platforms." That is, areas where across our regional assets and industry, we have capabilities that differentiate our region from other established and emerging clusters.

Data-Driven Healthcare and Connected Devices

If data is the new oil — with the real value derived from how it is processed and refined for meaningful use — then the Pittsburgh region is abundant in the raw materials and unique capabilities to apply that data to transformational human health innovation.

Beyond massive clinical and claims data from our integrated delivery and finance networks, we have rich data assets in biorepositories and unique databases tied to the University of Pittsburgh's robust history of NIH-funded research and collaboration. Add to that Carnegie Mellon University's top-ranked programs in AI, cyber security, and computer engineering and we have a world-class ecosystem that is making massive strides in health information and informatics, computational biology, and connected devices.

Building on our robust existing cluster of medical device manufacturers, the region is well-positioned as the industry moves from stand-alone hardware to connected medical devices that leverage advanced analytics and two-way data capabilities.

These capabilities boost expansion and innovation at large, established companies, and fuel early-stage companies that are already lighting the industry on fire. This space is expected to grow to over \$500 billion per year by 2026.

Developing and Manufacturing Next-Generation Therapeutics

The world is moving from a one-size-fits-all approach toward precision medicine. The computational biology capabilities mentioned above paired with a visionary \$250 million investment by the RK Mellon Foundation and the University of Pittsburgh to establish BioForge, a 185,000-square-foot state-of-the-art biomanufacturing center, means the region can thrive in both identification, development, and manufacturing of these next-generation and life-changing therapeutic advancements.

Key partnerships with private sector leaders such as ElevateBio, combined with the region's long history of excellence in automation science, chemical engineering, and advanced manufacturing competitively position us as a first-class destination for developing specialized manufacturing techniques and producing precision biological therapeutics. Regional leaders should do everything they can to promote this opportunity for broad-based employment and economic growth in the future of medicine.

TEconomy's report also addresses ecosystem gaps that have limited growth in the sector to date. Unsurprising to many, the report notes the need to address regional limits in capital and managerial expertise and identifies opportunities for enhanced collaboration across the ecosystem. Targeted support of our differentiated "growth platforms" and strong articulation of our regional strengths will help attract investment and business activity from around the globe to our region.

Addressing these gaps will require constant collaboration. Based on this report, PLSA will convene working groups to prioritize, design, and pursue initiatives that will have the greatest impact on this dynamic ecosystem, while continuing our work to convene the ecosystem, communicate our strengths, and advocate for this shared vision. This is a once in a generation opportunity to seed decades of job growth and wealth creation in the region. Success hinges on a shared commitment by all stakeholders and decisive action by key entities and leaders.

Thank you to those who contributed to this work and all of those who will contribute to achieving the promised vibrancy of the life sciences sector in our region.

Most Sincerely,

Megan Shaw

President & CEO, Pittsburgh Life Sciences Alliance

Executive Summary

The future of healthcare and the life sciences is increasingly dependent on data and advanced analytics with far-reaching implications for patient care, research, and treatment outcomes.

Vast real-time data on vital signs and chronic conditions are now available through connected medical devices and remote patient monitoring systems, enabling healthcare providers to use predictive analytics that help optimize resources, intervene promptly, and enhance patient satisfaction. This wealth of newly available healthcare data, when combined with ever more robust biological data assets and advanced analytics techniques such as machine learning, is driving forward the field of precision medicine. The integration of data analytics in drug discovery and development is accelerating the identification of potential drug candidates and simulating therapeutics within the human body thereby reducing the time and cost required for drug development and clinical trials. By analyzing patient data at a granular level (e.g., genetic information, lifestyle factors, medical history, etc.), healthcare professionals are beginning to tailor treatment plans to an individual's unique characteristics, potentially improving outcomes and reducing adverse effects.

In addition to serving as a hub for clinical healthcare and health and life sciences education, Southwest Pennsylvania (the ten-county region¹ centered on Pittsburgh) has a long history of medical innovation. Supported by the University of Pittsburgh (Pitt), which consistently ranks among the top recipients of federal National Institutes of Health (NIH) research funding, and Carnegie Mellon University (CMU), an academic institution known for its advances in computer science (including machine learning, robotics, and computational biology), the Pittsburgh region is uniquely situated to lead the nation in the convergence of biological and data sciences. In addition, the region is home to two large healthcare providers, University of Pittsburgh Medical Center (UPMC) and Allegheny Health Network (AHN), and other smaller providers such as Indiana Regional Medical Center, Independence Health System, and Heritage Valley Health System. Combined, these institutions employ thousands of individuals, offer top-ranked services and specialties, and are advancing cutting-edge solutions related to digital platforms and artificial intelligence (AI) applications.

The Pittsburgh region has unquestionable strengths in life sciences research and development (R&D), which serves as a critical driver of the regional economy. Life sciences R&D funding grew by 26 percent in the Pittsburgh region between 2018-2022, reaching \$1.17 billion and outpacing the national average growth rate. Representing approximately 0.7 percent of the region's overall gross domestic product, academic life sciences R&D is more concentrated in the Pittsburgh region than in peer regions such as Boston and Nashville.

1 Includes Allegheny, Armstrong, Beaver, Butler, Fayette, Greene, Indiana, Lawrence, Washington and Westmoreland counties.

While life sciences academic research is a clear strength for the region, the commercial life sciences industry base is, by comparison, undersized.² Medical devices is the only life sciences subsector for which the region has a concentration of industrial activity that is above the national normative level. To foster greater levels of economic activity, there is an opportunity to convert R&D strengths into a robust pipeline of innovative companies across a breadth of commercial life sciences applications. This report is intended to identify the areas where the Pittsburgh region has differentiated strengths that can translate into robust economic growth, as well as potential actions that can help the region seize these opportunities.

The Pittsburgh region is home to two distinct, but interconnected, opportunities that are poised for growth—data-driven healthcare and connected devices and precision medicine and next-generation therapeutics. Building on the region’s unique core competencies, these technology platforms provide powerful opportunities for focused initiatives that will catalyze economic growth within two large-scale and fast-growing markets. Figure ES-1 illustrates the two platforms and associated regional core competencies and assets that link to these dynamic opportunities. Connecting the two platforms is the region’s leadership in data sciences and advanced analytics, fields that are increasingly central to advancing modern life sciences discovery and innovation.

Figure ES-1: Two Connected Platforms with Large-Scale Market Opportunities

	Data-Driven Healthcare and Connected Devices		Precision Medicine and Next-Generation Therapeutics		
Enabling Functionalities	Healthcare Data	Digital Health and Devices Industry	Discovery and Innovation	Contract Development and Manufacturing	Advanced Manufacturing Processes
Leading Institutions	UPMC, AHN, IRMC, others	Startups and Industry	Pitt/UPMC, CMU, AHN	BioForge/Elevate Bio	Cloud Lab, ARM, NREC
Technology Areas of Excellence	<ul style="list-style-type: none"> Health Informatics AI/ML/Automation Advanced Analytics IoT and Sensors Robotics Cybersecurity 		<ul style="list-style-type: none"> Clinical Excellence in Multiple Discovery Areas Computational Biology/ Informatics 	<ul style="list-style-type: none"> Regenerative Medicine Cell and Gene Therapy Chemical Engineering Automation Sciences 	
Rationale	<p>No place dominates in this yet, and the Pittsburgh region is well-positioned to advance the field based on key ecosystem assets and the already growing companies in the space.</p>			<p>Despite a limited presence of traditional small/large molecule drug companies in region, this is an opportunity to build new presence in a fast emerging and disruptive space.</p>	

Source: TEconomy Partners, LLC

² For the purposes of this report, the life sciences refer to activities related to human health and includes pharmaceuticals, medical devices, and other health technologies. This definition does not include animal health, agricultural life sciences, or general healthcare delivery.



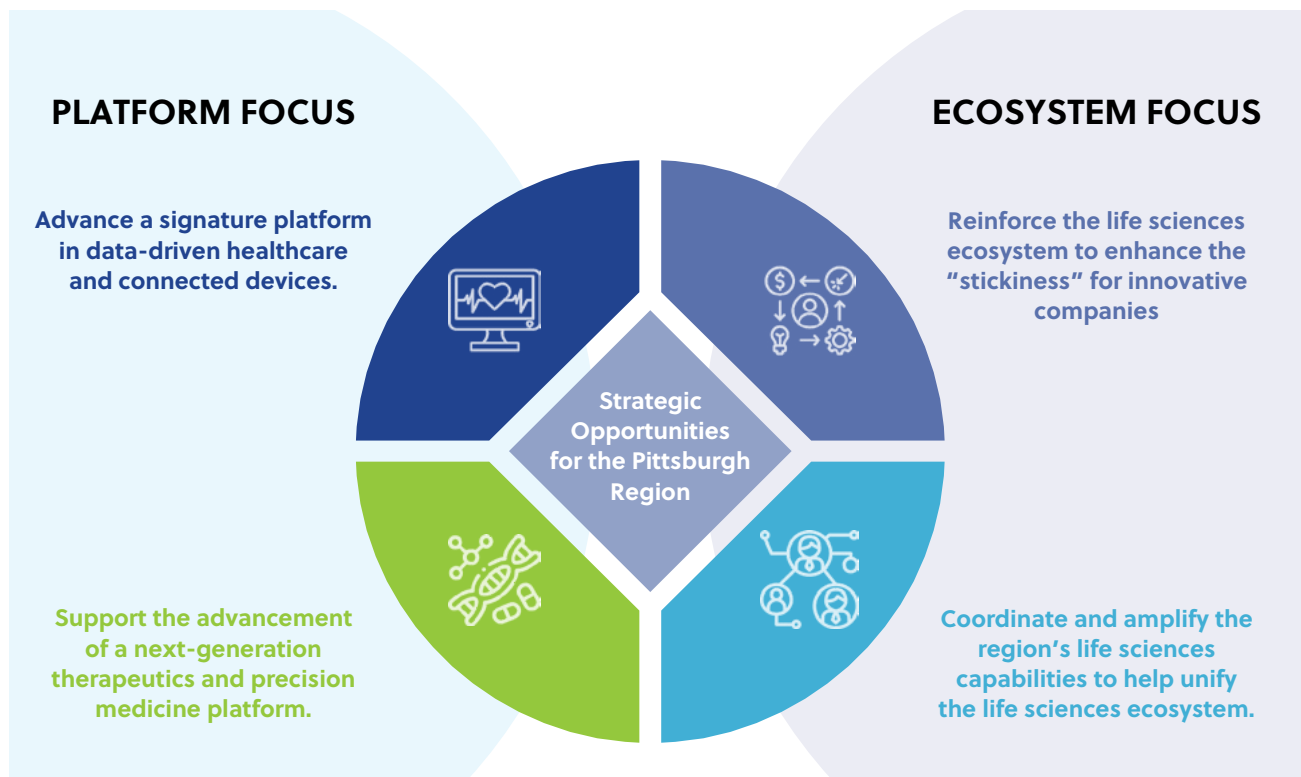
It is important to note that simply creating signature research strengths is not sufficient to foster the development of a life sciences industrial cluster in the region. In fact, despite the Pittsburgh region's existing strengths in academic R&D, it has been only moderately successful in translating its research into commercial opportunities. Ecosystem challenges include cultivating industry partnerships, attracting venture capital, and developing high-growth, innovative companies at scale. As a result of not having a shared vision for the region, resources have often been spread across a range of disconnected activities. While the Pittsburgh region has been successful at winning NIH awards and conducting basic research, there is a disconnect between the region's academic strengths and translational research aligned with industry demand. As long as this disconnect persists, the Pittsburgh region will continue to punch below its weight and fail to realize the opportunity for life sciences to be a transformational growth industry for the region.

To overcome these challenges, take advantage of the Pittsburgh region's unique life sciences opportunities, and build a world-class life sciences industry cluster in the Pittsburgh region, a SHARED strategy and action plan is required. Built upon the findings from in-depth quantitative and qualitative assessment techniques, together with input and review from the Strategic Advisory Committee and multiple regional stakeholders, four primary strategies listed below and illustrated in Figure ES-2 and fourteen associated actions (Table ES-1) are recommended:

- 1. Advance a signature platform in data-driven healthcare and connected devices:** Leverage world-class assets in data science, advanced analytics, healthcare operations, clinical trials, healthcare system data platforms, and medical devices to advance innovations in health tech, connected devices, smart healthcare, and data-empowered drug discovery.

2. **Advance a next-generation therapeutics and precision medicine platform:** Leverage BioForge to foster innovations and breakthroughs in the manufacturing of precision biologic medicines, enhance the speed and quality of advanced therapeutics production, and develop a precision medicine ecosystem and supply chain through business attraction and development efforts.
3. **Reinforce the life sciences ecosystem to enhance the “stickiness” for innovative companies:** Support the next generation of life sciences companies by attracting and cultivating management talent, incentivizing faculty to engage in entrepreneurship, attracting growth capital, and aligning educational programs with industry needs.
4. **Coordinate and amplify the region’s life sciences capabilities to help unify the life sciences ecosystem:** Enhance the region's competitive position in the life sciences sector through the implementation of a collaborative regional life sciences strategy, including targeted branding, ecosystem alignment through multi-party collaboration, and funding for execution.

Figure ES-2: Visualization of Core Strategies



Source: TEconomy Partners, LLC

Table ES-1: Summary of Strategic Actions

Strategy 1: Advance a signature platform in data-driven healthcare and connected devices.	
Action 1.1	Build a dominant position in data-driven healthcare innovation.
Action 1.2	Advance programs for health systems to provide a “voice of customer” to industry and academia.
Action 1.3	Connect, grow, and retain region’s connected device industry.
Strategy 2: Support the advancement of a next-generation therapeutics and precision medicine platform.	
Action 2.1	Leverage BioForge to establish a regional strength in enhancing the speed and quality of advanced therapeutics production.
Action 2.2	Encourage growth in clinical trials to accelerate new therapeutic development.
Action 2.3	Further develop the precision medicine ecosystem and supply chain with targeted business attraction and development efforts.
Strategy 3: Reinforce the life sciences ecosystem to enhance the “stickiness” for innovative companies.	
Action 3.1	Support the next generation of life sciences companies by attracting and cultivating management talent with an emphasis on targeted platforms.
Action 3.2	Encourage a commercialization and entrepreneurial mindset at research-intensive universities.
Action 3.3	Attract new forms of risk capital to the region.
Action 3.4	Translate and connect industry needs to educational providers and workforce partners across the educational continuum.
Strategy 4: Coordinate and amplify the region’s life sciences capabilities to help unify the life sciences ecosystem.	
Action 4.1	Develop a targeted branding/storytelling campaign around the region’s life sciences assets and opportunities.
Action 4.2	Align regional life sciences ecosystem components to ensure collaborative strategy implementation (“Collaborate to Compete”).
Action 4.3	Advocate for the life sciences strategy as a means to accomplish regional goals.
Action 4.4	Empower industry-driven points of view to solve ecosystem gaps.

Source: TEconomy Partners, LLC

The recommendations focus on building a flexible and holistic ecosystem to support life sciences companies and identify pathways to build signature platform opportunities. These recommendations address barriers to business development and commercialization. They also provide connections and support for life sciences companies, resulting in a robust ecosystem that stimulates growth and advances human health innovations.

Estimating the Pittsburgh Region's Life Sciences Industry Economic Growth Potential

The Pittsburgh region has the opportunity to grow its life sciences ecosystem and related industry cluster. Investment in life sciences translational research and development, and associated economic development supports, will help diversify the regional economy with a resilient industry that offers good paying jobs with high-growth potential.

Already, the life sciences are an important sector for the regional economy. In 2023, the Pittsburgh region's life sciences industry accounted for \$3.4 billion in regional economic output and more than 15,500 jobs.³

However, the region's life sciences industry is undersized when compared to levels of overall academic life sciences R&D:

- *If the Pittsburgh region's ratio of life sciences industry output to academic R&D matched the national average, the estimated size of the region's industry today would be more than 4X greater—\$14.3 billion, or an additional \$10.9 billion in estimated economic output.*
- *If the Pittsburgh region's ratio of life sciences industry employment to academic R&D matched the national average, the estimated size of the industry today would be nearly 3X greater—more than 41,000 total employees, or an additional 25,800 industrial life sciences jobs.*

Furthermore, in terms of both employment and output, regional growth rates lagged the nation. A fundamental goal for the Pittsburgh region should be to match the national averages in life sciences industry output and employment growth. Doing so would have significant positive effects on the regional economy:

- *If the Pittsburgh region's life sciences industry output had grown at the same rates as the national average from 2018-2023 (28 percent vs. 38 percent), the estimated size of the regional industry today would be nearly \$3.7 billion—an additional \$268.5 million in estimated economic output.*
- *If the Pittsburgh region's life sciences industry output had grown at the same rates as the national average from 2018-2023 (9 percent vs. 21 percent), the estimated size of the regional industry today would be nearly 17,300—adding 1,700 jobs to the economy.*

To realize these economic gains, the region needs to work to outpace national average growth. The region has an opportunity to invest in distinctive life sciences opportunities that will position the region to move beyond a conservative "national average" growth goal. By working to reinforce the regional life sciences economic development ecosystem and **focusing on core competency-based opportunities with a clear line-of-sight to large-scale market opportunities**, the Pittsburgh region can realign its growth trajectory and better leverage its world-class research to enable commercial life sciences industry growth.

3 TEconomy's analysis of QCEW data via Lightcast (datarun 2024.2)



Conclusion

The Pittsburgh region stands at a pivotal moment in its evolution as a leader in human health innovation. With a rich history of medical advancements and strong institutional support from key organizations, including Pitt, UPMC, AHN, CMU, and a growing base of life sciences companies, the region is well-positioned to capitalize on its strengths. There are two robust opportunities for focused R&D and cluster development that are poised for rapid market growth—data-driven healthcare and connected devices and next-generation therapeutics and precision medicine. However, to fully realize its potential, the region must implement a unified and cohesive strategy that enhances its life sciences ecosystem. This involves establishing dominance in data-driven healthcare, leveraging the BioForge initiative for advanced therapeutics, and fostering a supportive environment for life sciences companies through talent cultivation and capital attraction. By coordinating regional capabilities and aligning efforts through collaborative strategies, the Pittsburgh region can transform its academic and research prowess into a world-class life sciences industry cluster, driving significant economic growth and innovation in the healthcare sector.

Setting the Context

As home to leading healthcare systems (UPMC and Allegheny Health Network (AHN)-Highmark), distinguished universities (Carnegie Mellon University and the University of Pittsburgh), and an existing life sciences industry cluster comprised of both global players (e.g., Zoll, Bayer, Thermo Fisher Scientific, and Smith & Nephew) and emerging startups (e.g., Abridge, Blue Sphere Bio, Free Market Health, Lygenesis, and Peptilogics), Southwest Pennsylvania (the Pittsburgh region) is well-positioned to be a leading location for human health innovation.

The Pittsburgh region's historic contributions to the life sciences are profound and diverse, including the development of the Polio Vaccine and the first simultaneous heart, liver and kidney transplant. With significant changes expected to impact the life sciences in the coming years, the Pittsburgh region has a unique opportunity to seize upon its recent momentum.

In April 2024, the Pittsburgh Life Sciences Alliance (PLSA) was launched as a nonprofit, membership-based organization dedicated to developing, promoting, and helping to curate the strategic direction of the region's life sciences industry. Tasked with leveraging the region's significant life sciences assets, PLSA is focusing on establishing the Pittsburgh region both as an internationally recognized research leader as well as a powerful hub of industry, entrepreneurship, investment and innovation.

As a first step, PLSA identified a need to develop a strategic opportunity analysis to help chart a course for the region's life sciences sector with a focus on human health innovation. Led by PLSA, the analysis has been developed under the guidance of a Strategic Advisory Committee (SAC). The SAC includes leadership from industry, higher-education, healthcare, philanthropy, and economic development (Figure 1). Over the course of six months, the SAC met to understand the region's competitive position in the life sciences and associated technologies, to review analytical findings, to hear insight from regional stakeholders (see Appendix A), to gauge the performance of competitor regions, and to learn about best practices being implemented in other areas.

Figure 1: Organizations Participating in Strategic Advisory Committee



Source: TEconomy Partners, LLC

TEconomy Partners, LLC (TEconomy) was engaged by PLSA to develop the analysis to help inform the region’s strategic decisions regarding potential future investments and programmatic initiatives. To highlight opportunities and challenges facing the region, TEconomy used a mixed-methods approach that combines extensive quantitative data analysis alongside thorough qualitative engagement with regional thought leaders (Figure 2). The key findings and resulting recommendations from the analysis are the subject of this report and its technical appendices.

Figure 2: Situational Assessment Based on Quantitative and Qualitative Inputs

Strategic Advisory Committee	Quantitative Analysis	Stakeholder Outreach	Benchmarking and Best Practices																																				
<p>Representation from some of region’s leading life sciences companies, health-care systems, research universities, philanthropies, and economic development organizations.</p> <p>Feedback through one-on-one interviews, group discussions, and a survey.</p>	<p>Technology Push</p> <ul style="list-style-type: none"> • Publications analysis • NIH funding and themes • Existing research institutes • Clinical trials activity • IP generation <p>Industry Pull</p> <ul style="list-style-type: none"> • Industry positioning and performance • Presence of leading companies • Industry patent activity • New ventures & VC activity 	<p>30+ One-on-One Interviews:</p> <table border="0"> <tr> <td><u>Industry</u></td> <td><u>Health Systems:</u></td> </tr> <tr> <td>• Bayer</td> <td>• AHN</td> </tr> <tr> <td>• Cook Myosite</td> <td>• IRMC</td> </tr> <tr> <td>• M*Modal</td> <td>• UPMC</td> </tr> <tr> <td>• Predictive Oncology</td> <td>• Higher-Ed</td> </tr> <tr> <td>• Smith & Nephew</td> <td>• Carnegie Mellon</td> </tr> <tr> <td>• Teletracking</td> <td>• CCAC</td> </tr> <tr> <td>• ThermoFisher</td> <td>• Pitt</td> </tr> <tr> <td>• ZOLL</td> <td></td> </tr> <tr> <td><u>Startups/VC:</u></td> <td><u>Other Life Sciences Ecosystem:</u></td> </tr> <tr> <td>• Abridge</td> <td>• ACCD</td> </tr> <tr> <td>• BlueSphere</td> <td>• Hillman Fdn.</td> </tr> <tr> <td>• Free Market Health</td> <td>• Mellon Fdn.</td> </tr> <tr> <td>• Lygenesis</td> <td>• RIDC</td> </tr> <tr> <td>• Net Health</td> <td>• Innovate PGH</td> </tr> <tr> <td>• Peptilogics</td> <td>• LifeX</td> </tr> <tr> <td>• Realyze</td> <td>• Innovation Works</td> </tr> <tr> <td>• UPMCE</td> <td></td> </tr> </table>	<u>Industry</u>	<u>Health Systems:</u>	• Bayer	• AHN	• Cook Myosite	• IRMC	• M*Modal	• UPMC	• Predictive Oncology	• Higher-Ed	• Smith & Nephew	• Carnegie Mellon	• Teletracking	• CCAC	• ThermoFisher	• Pitt	• ZOLL		<u>Startups/VC:</u>	<u>Other Life Sciences Ecosystem:</u>	• Abridge	• ACCD	• BlueSphere	• Hillman Fdn.	• Free Market Health	• Mellon Fdn.	• Lygenesis	• RIDC	• Net Health	• Innovate PGH	• Peptilogics	• LifeX	• Realyze	• Innovation Works	• UPMCE		<p>Analyzed Pittsburgh and four benchmark regions:</p> <ul style="list-style-type: none"> • Boston • Research Triangle • Seattle • Nashville <p>Analyzed best practice programs and quantitative performance in:</p> <ul style="list-style-type: none"> • Life sciences R&D • Technology transfer and commercialization • Venture capital • Industry performance • Talent development
<u>Industry</u>	<u>Health Systems:</u>																																						
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<p>Focus Groups</p> <p>Three focus groups with 30 total participants</p>																																							

Source: TEconomy Partners, LLC

Situational Analysis: Understanding the Performance of the Pittsburgh Region's Life Sciences Ecosystem

Robust strategic planning efforts help to build more comprehensive ecosystems that assist innovators, entrepreneurs, industry leaders, and other stakeholders to navigate increasingly complex, competitive, and demanding markets.⁴

For economic development strategic planning to be successful, it must be grounded in robust quantitative analytics while at the same time being responsive to situational nuances drawn from extensive qualitative inputs. Rooted in more than 30 years of advanced science-, technology-, and innovation-led economic development practice, it is evident that successful strategies are:

- Driven by public/private partnerships.
- Able to leverage other programs/investments to exhibit relevancy to broader economic development efforts in order to develop critical mass and efficiencies.
- Flexible so programs can evolve while maintaining alignment to the overall key mission.
- Built with communication/feed-back loops to ensure long-term commitment by key stakeholders.
- Structured to advance signature development "platforms" that are rooted in existing and emerging R&D core competencies with a line-of-sight to large-scale market and cluster-building opportunities.

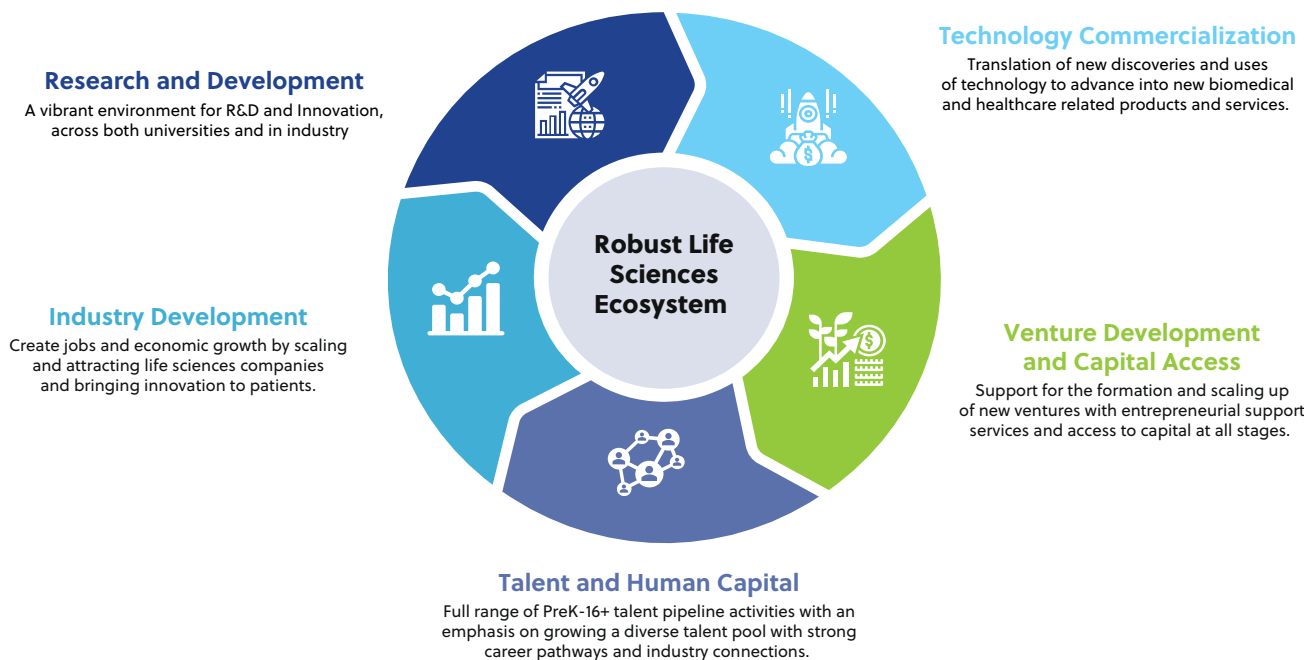
Assessing the performance, trends, and position of the Pittsburgh region's life sciences industry performance, as well as the region's research activities and overall innovation ecosystem capabilities, is a critical component of the strategic planning process. While some regions may be able to develop sites for biosciences manufacturing or distribution based on their general business conditions and infrastructure, the ability to sustain and broaden growth in the life sciences depends upon the ability to create and capture opportunities for market leading innovation. Across the nation, a select set of regions with significant life sciences assets have effectively implemented strategic plans/initiatives to encourage cluster development (such as Boston, Research Triangle, San Diego, and Indianapolis), while other regions with significant life sciences research assets have struggled to build momentum and move beyond medical research capabilities (such as Cleveland, Baltimore, and New Haven). The Pittsburgh region presently is more in the latter category than the former.

⁴ <https://sloanreview.mit.edu/article/strategically-engaging-with-innovation-ecosystems/>

As Figure 3 illustrates, key elements to consider when assessing the performance and position of a region's life sciences ecosystem include:

- **Research and Development** - life sciences research core competencies found at universities, academic medical centers, and nonprofit research institutes.
- **Technology Commercialization** - translational innovation and technology development capacities involving patenting of inventions, university technology transfer and commercialization, and clinical trials testing of new medicines and devices.
- **Venture Development and Capital Access** - support for the formation and scaling of new ventures, including access to risk capital across the funding continuum from pre-seed (incubation and acceleration) to angel investments to seed and early stages to later rounds of formal venture capital.
- **Industry Development** - life sciences industry development across the major industry subsectors that span drugs and pharmaceuticals, medical devices, commercial research and testing, distribution, health technologies, and healthcare delivery.
- **Talent and Human Capital** - life sciences skills development across the entirety of the talent pipeline, including educational and workforce development programs at schools, universities, community colleges, and other flexible learning opportunities.

Figure 3: Elements of a Robust Life Sciences Ecosystem



Source: TEconomy Partners, LLC

Evaluation of the Pittsburgh region’s strengths and weaknesses across these key elements found that:

The Pittsburgh region’s life sciences R&D expertise is both broad and deep.

The Pittsburgh region benefits from an especially robust position in academic life sciences R&D, and it is an important component of the economy. By attracting external R&D funding, academic R&D effectively serves as a traded sector for the region that supports economic growth. Life sciences R&D funding grew by 26 percent from 2018-2022, reaching \$1.17 billion and outpacing the national growth rate.⁵ The life sciences are the largest component of academic R&D in the region, representing 68 percent of total R&D expenditures in 2022. Life sciences R&D is driven by Pitt, a world-class center of health and life sciences research that ranks in the top five nationally for number of NIH awards and in the top ten for total NIH funding.⁶

Academic R&D funding has led to considerable publication activity—more than 101,000 life sciences research publications since 2018.⁷ Pittsburgh is home to a demonstrably broad base of academic excellence, and analysis against national normative levels finds 23 life-science associated publication fields where Pittsburgh has a very specialized position as measured by publications quotient (Figure 4).⁸ The most concentrated areas of publication activity are in critical care medicine, transplantation, respiratory systems, and gastroenterology hepatology.⁹ Oncology, surgery, pediatrics, clinical neurology, cardiac cardiovascular systems, robotics, and computer sciences artificial intelligence stand out as areas with a high level of publications output and demonstrated specialization. Notably, three of the region’s most specialized strengths in life sciences are in health-tech related fields: robotics (90 percent more specialized than the nation), cybernetics (60 percent), and artificial intelligence (50 percent).

5 TEconomy’s analysis of NSF HERD Data

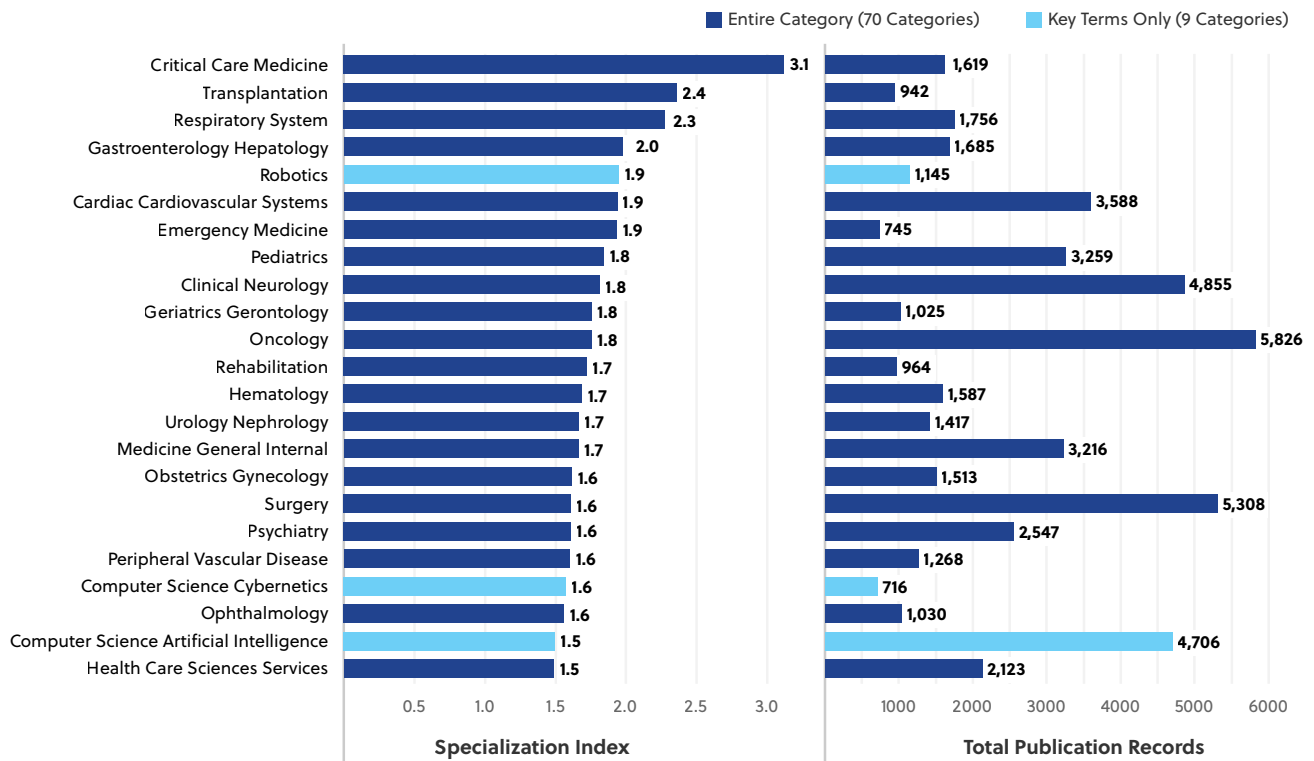
6 TEconomy’s analysis of NIH Awards

7 TEconomy’s analysis of data from the Clarivate Analytics’ Web of Science publications analysis database

8 *Ibid*

9 The Publication Quotient is a measure of the degree to which a certain subject is less, the same as, or more concentrated in a region than it is across the nation overall. A quotient of 1.0 is equivalent to a region having the same concentration of publishing in a topic as the nation. Less than 1.0 would be less concentrated, while greater than 1.0 would be more concentrated. Generally, any topic having a publications quotient above 1.2 is considered evidence of specialization. A topic with a publications quotient above 1.5 is considered very specialized.

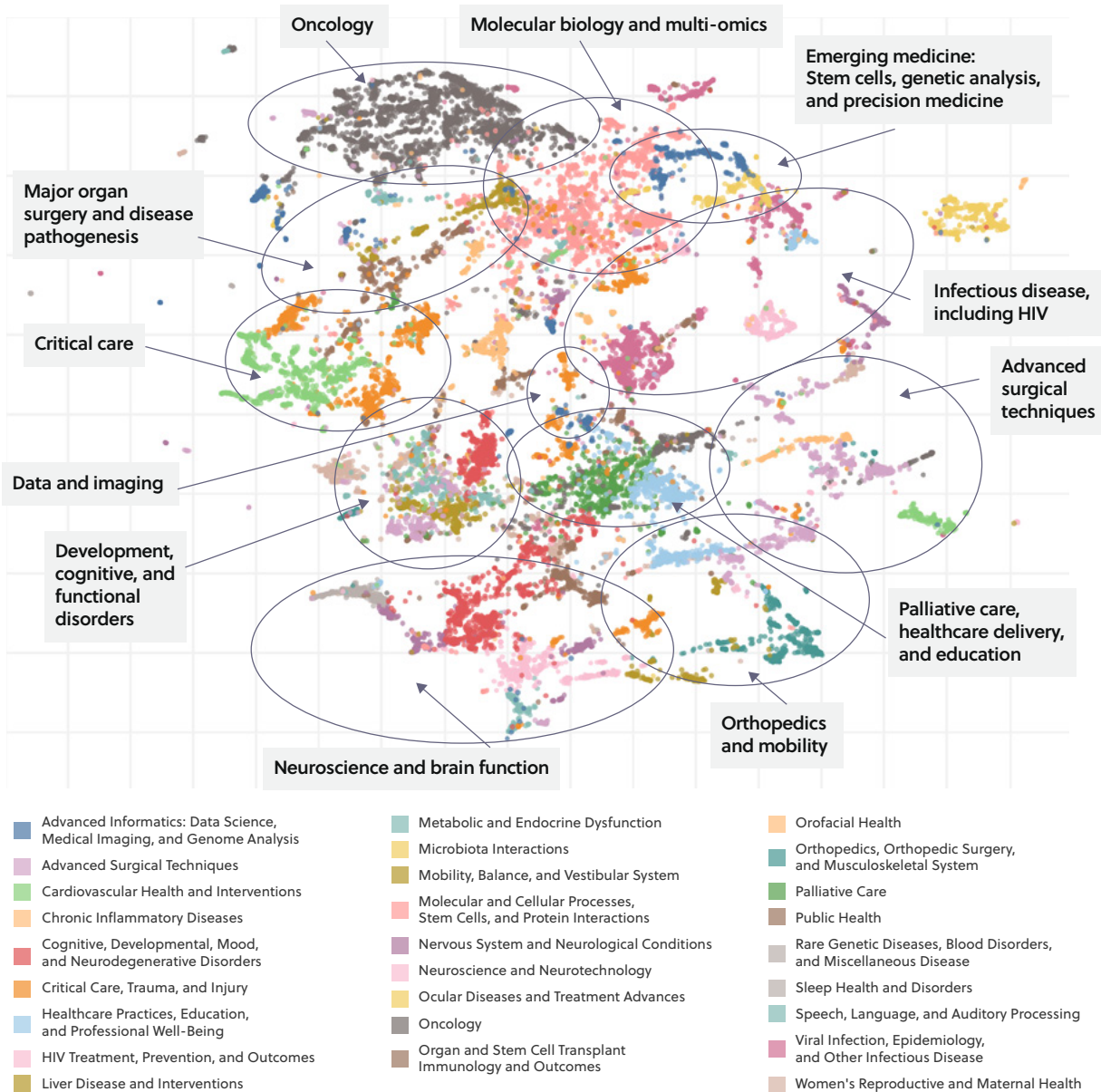
Figure 4: Areas of Publication Specialization in the Pittsburgh Region



Source: TEconomy’s analysis of data from the Clarivate Analytics’ Web of Science publications analysis database

To better understand the region’s life sciences research landscape, TEconomy conducted a topic model analysis of research publications that categorized individual publications records by their text content (see Appendix C). Natural language processing and clustering approaches serve to identify detailed topic themes within the body of research activity, which can then be visualized to understand the structure of thematic areas present. This analysis works independently of the previously cited Web of Science (WoS) classifications to build analysis from the ground up with no a priori publication groupings. The dataset examined included 37,421 research publications from the Pittsburgh region (2018 to date) captured using life science-related keywords. This advanced analysis of publications finds key strengths in oncology, molecular/cellular processes, critical care, viral diseases, and cognitive health (Figure 5). This analysis also finds that advanced informatics (blue) interacts with many topics and categories, which suggests that this is a cross-cutting theme for the region’s life sciences researchers.

Figure 5: Network Map of Leading Life Sciences Publication Areas in the Pittsburgh Region



Source: TEconomy's analysis of data from the Clarivate Analytics' Web of Science publications analysis database

Understandably, having such a diverse base of R&D competencies has made it difficult to structure and convey an opportunities-based narrative that encompasses the region's numerous R&D strengths. The region has historically struggled to build an identity for its large-scale health and life sciences sector that adequately conveys the powerful strengths of the region, and the opportunities presented for innovation-based economic growth rooted in its core competencies.

Stakeholders across the region noted there is an ongoing need for the ecosystem to better align across shared strengths and prioritize a limited number of signature areas. There is also a sense that simply attracting additional federal R&D funding is not sufficient to drive economic growth. While the region has been successful in growing its research base, there are concerns that this has not led to widespread commercialization and economic/industry growth. There are also concerns that the region engages in comparatively low levels of industry-funded life sciences research compared to benchmarks and the U.S. average.¹⁰

The Pittsburgh region is effectively commercializing its research when compared to other regions.

The Pittsburgh region ranks quite well in overall technology transfer and commercialization metrics when compared to benchmarks. As measured against four other regions (Boston, Nashville, Research Triangle, and Seattle), the research universities in the Pittsburgh region fare positively (Table 1). When normalizing by total academic R&D, the region’s research-intensive universities rank highly across the number of licenses, inventions, patents, and startups. Despite these strengths, regional entrepreneurs and faculty noted frustration with the time it takes to execute licenses and other agreements, suggesting there is opportunity for even greater commercialization activity.

Table 1: Regional Ranking of Commercialization Measures Normalized by Total Research Expenditures from Participating Universities (HERD)

Region*	Total Licenses/ Options Executed	Gross Licensing Income	Invention Disclosures Received	New Patent Applications Filed	Issued U.S. Patents	Startups Formed
Pittsburgh Region	2	4	2	2	2	2
Boston MSA	5	1	1	1	1	1
Nashville MSA	4	2	4	3	3	5
Research Triangle	3	3	3	4	4	3
Seattle MSA	1	5	5	5	5	4

Source: TEconomy’s analysis of AUTM and HERD Data (averages 2018-2022). Analysis includes Pitt, CMU, Harvard, MIT, Boston U., Tufts, Northeastern, NCSU, UNC-Chapel Hill, Duke, Washington, and Vanderbilt.

10 TEconomy’s analysis of NSF HERD data

From a small base, the Pittsburgh region is seeing growth in life sciences venture capital.

Growth in potential commercial opportunities and deal-flow has helped to fuel improved venture capital attraction in the Pittsburgh region. Regional partners, such as UPMC Enterprises (UPMCE), LifeX, and Innovation Works, are among leading providers of pre-seed funding for life sciences companies. Starting from a relatively small base of 29 deals and \$54 million in 2018, life sciences venture capital (VC) activity grew substantially from 2018-2023 (Figure 6). The number of regional life sciences VC deals has grown 70 percent since 2018, far outpacing the Commonwealth of Pennsylvania (10 percent increase) and the nation (no change) as well as all the benchmarked regions. The amount of VC investment in the region's life sciences industry has more than tripled since 2018, far outpacing the U.S. (20 percent increase) and that of Pennsylvania (10 percent decrease). The leading areas for life sciences investment include drug discovery, healthcare technology systems, and biotechnology products.

Figure 6: Growth in Pittsburgh Regional Life Sciences VC Deals and Investment



Source: TEconomy's analysis of Pitchbook data

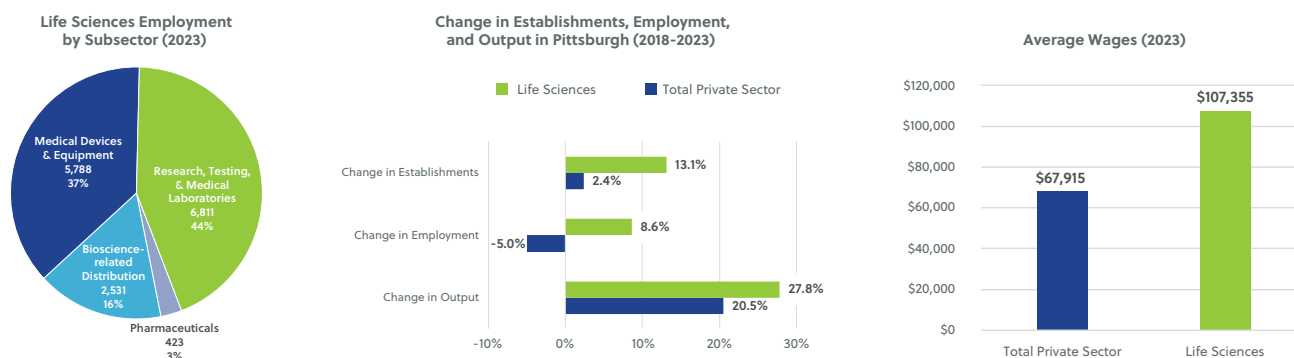
However, considering the base of academic R&D, the region is still underperforming in venture capital, lagging all benchmarks in the amount of life sciences venture funding from 2018-2023.¹¹ The lack of access to capital can be particularly stark for startups emanating from the university's research institutions. A lack of access to capital (as well as a lack of life sciences-related business management talent and development facilities) inhibits the growth and scalability of local life sciences companies. With the exception of UPMCE, capital is generally limited in the region for larger rounds, which often requires coastal investors.

11 TEconomy's analysis of Pitchbook data

The Pittsburgh region's life sciences industry is helping drive regional growth, but it is undersized for its potential.

The Pittsburgh region's private sector life sciences industry contributes substantially to regional growth. With nearly 16,000 employees, the Pittsburgh region's life sciences industry pays higher wages and is growing faster than the region's private sector in establishments, employment, and output (Figure 7). The region is seeing employment growth across all life sciences subsectors, led by R&D services. However, medical devices are the region's only subcluster where employment is specialized (82 percent more concentrated than the nation).¹² Despite employment growth across most industrial life sciences subsectors, the region's rates of growth since 2018 have been slower than the nation, which suggests it is losing market share.

Figure 7: Performance of the Pittsburgh Region's Life Sciences Industry



Source: TEconomy's analysis of QCEW data via Lightcast (datarun 2024.2).

In 2023, the Pittsburgh region's life sciences industry accounted for \$3.4 billion in economic output and more than 15,500 jobs.¹³ However, the region's life sciences industry is undersized when compared to levels of overall academic life sciences R&D:

- *If the Pittsburgh region's ratio of life sciences industry output to academic R&D matched the national average, the estimated size of the region's industry today would be more than 4X greater—\$14.3 billion, or an additional \$10.9 billion in estimated economic output.*
- *If the Pittsburgh region's ratio of life sciences industry employment to academic R&D matched the national average, the estimated size of the industry today would be nearly 3X greater—more than 41,000 total employees, or an additional 25,800 industrial life sciences jobs.*

Furthermore, in terms of both employment and output, regional growth rates lagged the nation. If the Pittsburgh region were to match national averages in life sciences industry employment and output growth, this could have significant impacts on the regional economy:

¹² TEconomy's analysis of QCEW data via Lightcast (datarun 2024.2). Includes only human biomedical life sciences fields and does not include healthcare or agricultural biosciences.

¹³ TEconomy's analysis of QCEW data via Lightcast (datarun 2024.2).

- ***If the Pittsburgh region's life sciences industry output had grown at the same rates as the national average from 2018-2023 (28 percent vs. 38 percent), the estimated size of the regional industry today would be nearly \$3.7 billion—an additional \$268.5 million in estimated economic output.***
- ***If the Pittsburgh region's life sciences industry output had grown at the same rates as the national average from 2018-2023 (9 percent vs. 21 percent), the estimated size of the regional industry today would be nearly 17,300—adding 1,700 jobs to the economy.***

Despite its levels of research excellence, the region is underperforming in terms of leveraging research-based innovations to generate new commercial life-science ventures that locate and scale in the region. The region also faces challenges attracting existing life sciences companies to move into the region and take advantage of R&D competencies.

Life sciences-related scientific and technical talent is a strength for the Pittsburgh region.

The Pittsburgh region is seeing growth in life sciences degree production. The number of life sciences degrees conferred in the Pittsburgh region grew 14 percent over five years to reach nearly 1,500 life sciences bachelor's degrees in 2022 and roughly 2,000 total degrees.¹⁴ Importantly, top-tier talent and educated young workers were commonly cited as a regional strength during interviews. Nearly every institution of higher education across the Pittsburgh region offers a robust portfolio of healthcare and life sciences programs. This speaks to the region's collective capacity to produce relevant talent and evolve training capabilities in sync with industry needs.

Recent analysis from CBRE finds that the Pittsburgh region is a fast-growing market for life sciences degrees and leads the nation in the share of graduates relative to the size of local industry.¹⁵ The analysis finds that the region ranks 17th in growth in life sciences degrees 2017-22 and ranks 11th in 2022 life sciences graduates. Notably, the report finds that, "among the top 25 life sciences R&D markets, Pittsburgh ranks first in producing the most biological and biomedical sciences graduates relative to its industry size (0.6 new graduates per local life sciences R&D employee)." In contrast, Salt Lake City and the San Francisco area have the lowest graduate-to-industry size (<0.1).

14 TEconomy's analysis of NCES IPEDS Degrees at the associate's level and above. Analysis focuses on degrees most relevant to industrial life sciences, based on TEconomy's previous research and methodologies. Degree categories included in analysis include: biochemistry, biophysics and molecular biology; bioengineering and biomedical engineering; other biological and biomedical sciences; biological technician; biostatistics and bioinformatics; biotechnology; cell/cellular biology and anatomical sciences; epidemiology; general biology/biological sciences; general biomedical sciences; genetics & genomics; microbiological sciences and immunology; neurosciences; pharmacology & toxicology; and, physiology & pathology. The analysis does not include general healthcare degrees or animal, plant, or environmental sciences degrees.

15 CBRE, U.S. Life Sciences Talent Trends 2024: <https://www.cbre.com/insights/books/us-life-sciences-talent-trends-2024>

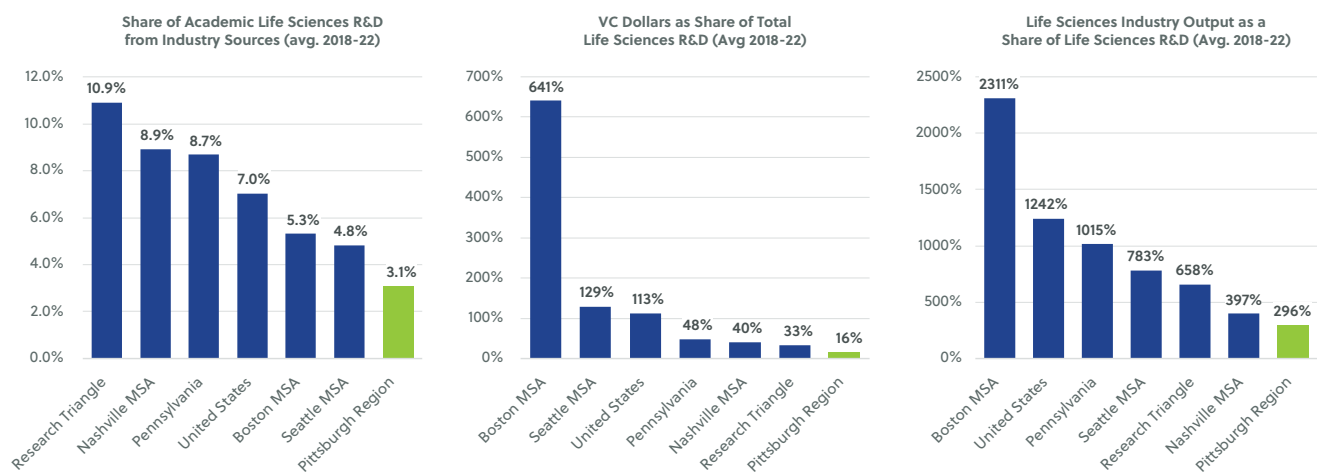
This discrepancy between life sciences talent development and industry growth is important to understand for the purposes of regional economic development. Without local industry jobs, graduates with industry-focused life sciences degrees will be highly likely to leave the region. As a result, there is a need to work with industry and educational providers to identify life sciences workforce development opportunities.

It is also important to note that human capital is not solely about bachelor’s and graduate degrees. As North Carolina has ably demonstrated, developing a skilled technical workforce for life sciences lab and production jobs can empower industry growth—assuring companies they can gain access to the workers they need for success. These jobs require skills that may be gained through community college courses and other sub-baccalaureate credential-oriented models. Beyond expertise in biological sciences, the growth of the sector also requires talent development for life sciences business management, regulatory affairs, quality control and compliance, and other areas that support critical business activities. Failing to build the right workforce mix threatens the region’s ability to attract, create, grow, and scale life sciences companies. There is a need to appropriately focus education and training programs to provide skills across the educational continuum to meet the needs of the health innovation ecosystem and associated industries.

Summary of Situational Assessment

From the analysis, it is apparent that life sciences R&D represents an important component of Pittsburgh’s regional economy. However, while the Pittsburgh region benefits from a robust position in academic life sciences R&D, the region underperforms across key metrics when standardizing by this value (Figure 8). Although the region has unquestionable strengths in academic R&D, it has been less successful in cultivating a world-class life sciences industry cluster. Challenges can be found in the region’s ability to create industry partnerships, in attracting venture capital, and in developing high-growth, innovative companies (at scale).

Figure 8: Metrics of Performance as a Share of Academic Life Sciences



Source: TEconomy’s analysis of NSF HERD, Pitchbook, and QCEW Data



Universities, health systems, healthcare payor organizations, and industries in different sectors of life sciences have different motivations and incentives that, without curated dialogue and a fostering of shared interests, will not naturally row in the same direction. While the economic development community comprises multiple organizations with a focus on life sciences development, or elements of it, it is clear that there is not a collective vision for what they seek to achieve as an effective operational ecosystem—nor is there agreement on swim lanes, gaps to address, or overall ecosystem coordination.

At this juncture, the Pittsburgh region would benefit from a shared strategy, created collaboratively and accepted by key stakeholders that enables mutually beneficial outcomes and regional economic growth to occur. Without such a strategy, it is likely that the region will continue to underperform in life sciences sector growth. The formation of the PLSA provides an opportunity to develop a strategy that allows the region to “collaborate to compete.” Rallying around a shared strategy for future investments and programmatic initiatives to enable the region as a global life sciences leader and economic engine.

Overview of the Strategic Opportunities for the Pittsburgh Region's Life Sciences Ecosystem

Opportunities

Based on the situational assessment of the greater Pittsburgh ecosystem, TEconomy has identified a set of potential actions regional stakeholders can take to build the region's capabilities and best position the region to capitalize on the economic potential of the two platforms that were identified. **To take advantage of the Pittsburgh region's unique life sciences core competencies and build a world-class life sciences industry cluster around forward-looking market opportunities**, four primary strategies are recommended:

1. **Advance a signature platform in data-driven healthcare and connected devices:** Leverage world-class assets in data science, advanced analytics, healthcare operations, clinical trials, healthcare system data platforms, and medical devices to advance innovations in health tech, connected devices, smart healthcare, and data-empowered drug discovery.
2. **Advance a next-generation therapeutics and precision medicine platform:** Leverage BioForge to foster innovations and breakthroughs in the manufacturing of precision biologic medicines, enhance the speed and quality of advanced therapeutics production, and develop a precision medicine ecosystem and supply chain through business attraction and development efforts.
3. **Reinforce the life sciences ecosystem to enhance the "stickiness" for innovative companies:** Support the next generation of life sciences companies by attracting and cultivating management talent, incentivizing faculty to engage in entrepreneurship, attracting growth capital, and aligning educational programs with industry needs.
4. **Coordinate and amplify the region's life sciences capabilities to help unify the life sciences ecosystem:** Enhance the region's competitive position in the life sciences sector through the implementation of a collaborative regional life sciences strategy, including targeted branding, ecosystem alignment through multi-party collaboration, and funding for execution.

Building on this situational assessment, as well as focus groups with a broad set of stakeholders, the strategic recommendations target distinct core competencies of the Pittsburgh region while also addressing ecosystem gaps—a strategy in two-parts that are closely linked, as visualized in Figure 9.

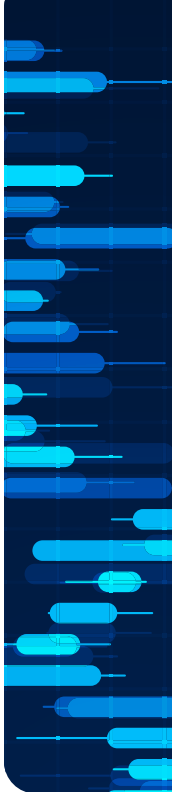
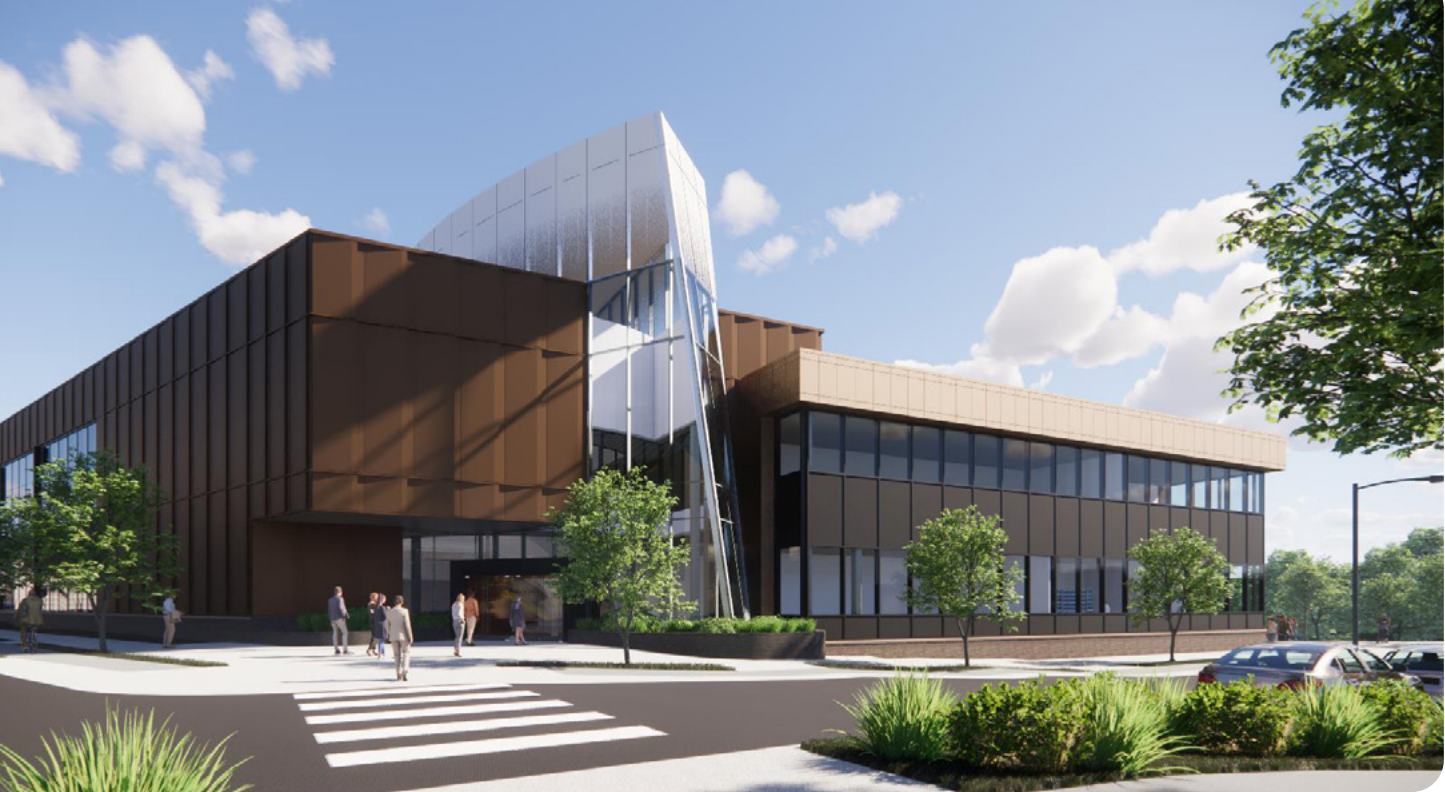
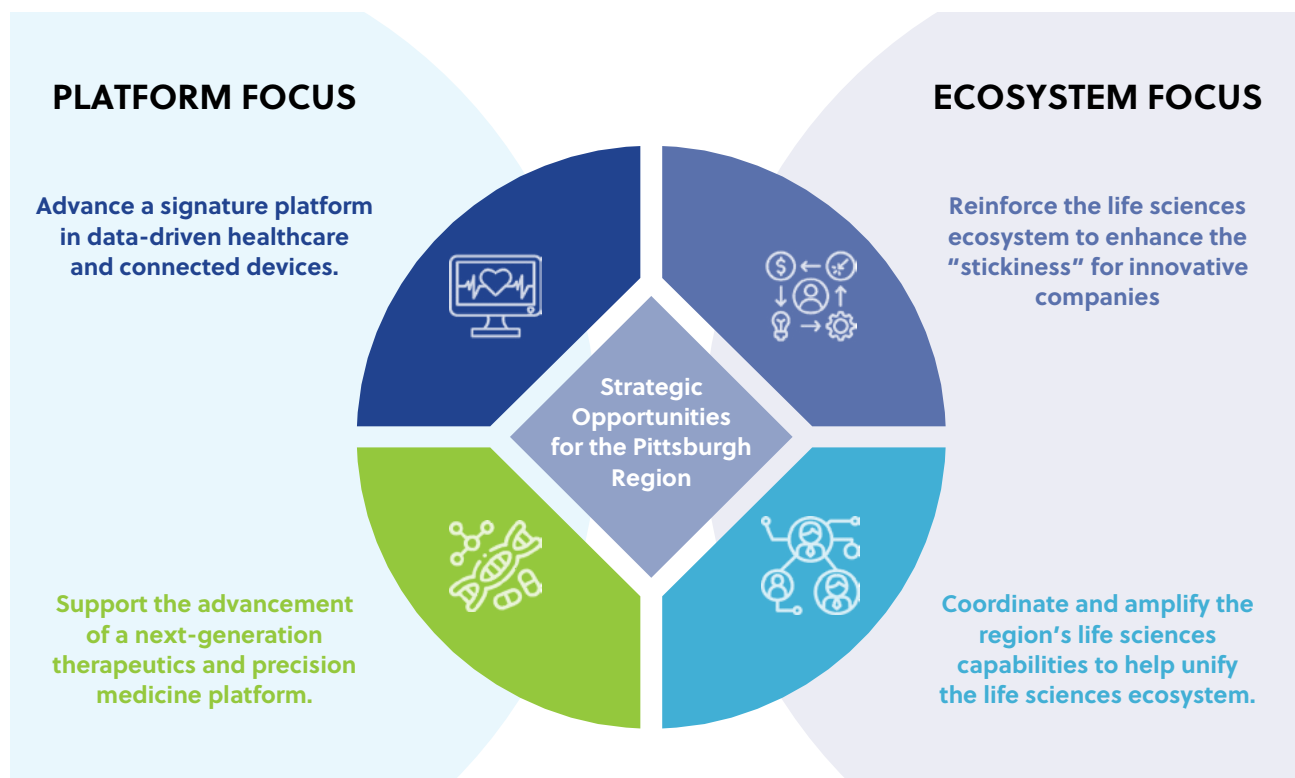


Figure 9: Visualization of Strategic Opportunities



Source: TEconomy Partners, LLC

It is proposed that PLSA and its strategic private sector, philanthropic, academic, and regional economic development partners advance these four opportunities and associated set of actions to leverage and complement existing efforts, while seeking to overcome remaining challenges and help catalyze the region's life sciences ecosystem (Table 2).

Table 2: Summary of Strategic Recommendations and Actions

Strategy 1: Advance a signature platform in data-driven healthcare and connected devices.	
Action 1.1	Build a dominant position in data-driven healthcare innovation.
Action 1.2	Advance programs for health systems to provide a “voice of customer” to industry and academia.
Action 1.3	Connect, grow, and retain region’s connected device industry.
Strategy 2: Support the advancement of a next-generation therapeutics and precision medicine platform.	
Action 2.1	Leverage BioForge to establish a regional strength in enhancing the speed and quality of advanced therapeutics production.
Action 2.2	Encourage growth in clinical trials to accelerate new therapeutic development.
Action 2.3	Further develop the precision medicine ecosystem and supply chain with targeted business attraction and development efforts.
Strategy 3: Reinforce the life sciences ecosystem to enhance the “stickiness” for innovative companies.	
Action 3.1	Support the next generation of life sciences companies by attracting and cultivating management talent with an emphasis on targeted platforms.
Action 3.2	Encourage a commercialization and entrepreneurial mindset at research-intensive universities.
Action 3.3	Attract new forms of risk capital to the region.
Action 3.4	Translate and connect industry needs to educational providers and workforce partners across the educational continuum.
Strategy 4: Coordinate and amplify the region’s life sciences capabilities to help unify the life sciences ecosystem.	
Action 4.1	Develop a targeted branding/storytelling campaign around the region’s life sciences assets and opportunities.
Action 4.2	Align regional life sciences ecosystem components to ensure collaborative strategy implementation (“Collaborate to Compete”).
Action 4.3	Advocate for the life sciences strategy as a means to accomplish regional goals.
Action 4.4	Empower industry-driven points of view to solve ecosystem gaps.

Source: TEconomy Partners, LLC

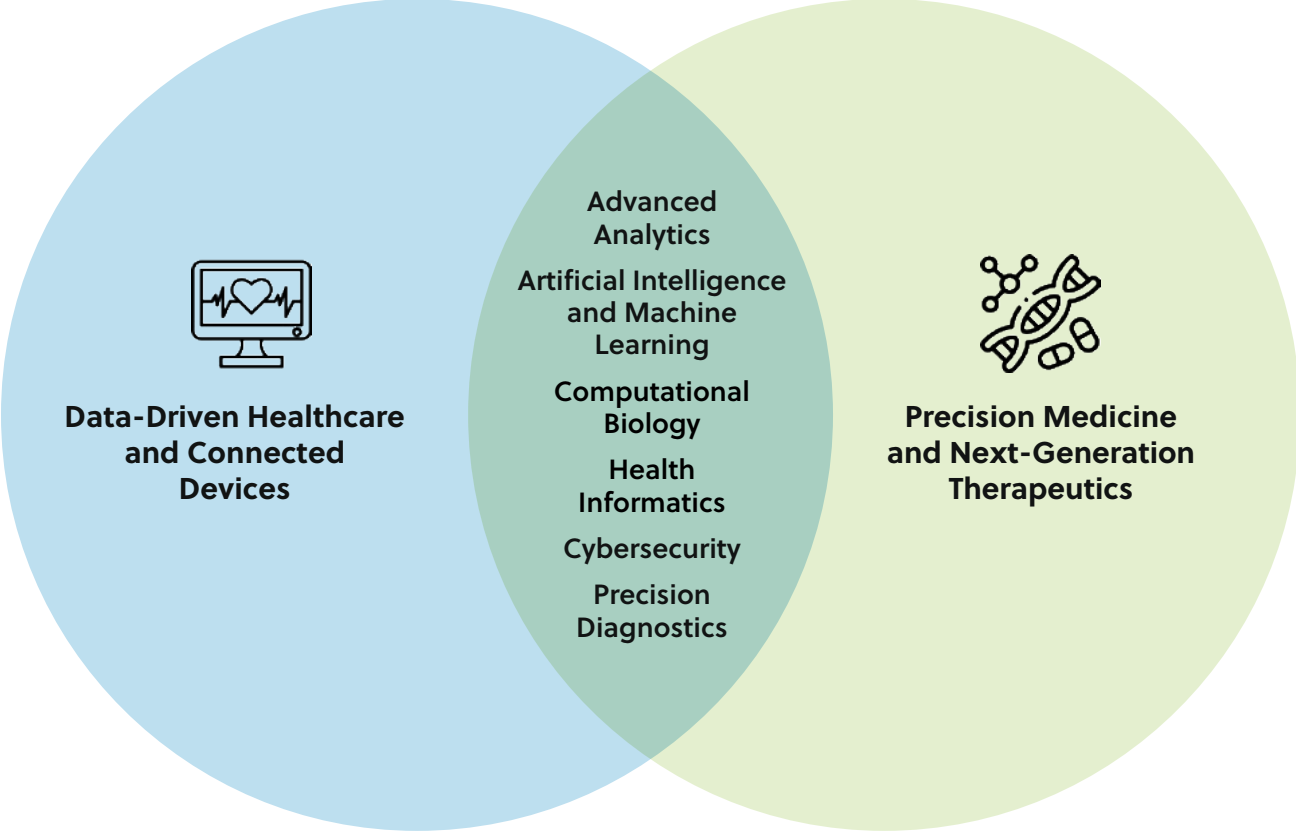
Strategies 1 and 2 are focused on advancing specific platforms for development. For opportunities to rise to the level of a “platform” they must demonstrate multiple favorable characteristics:

- They should be rooted in demonstrable established or rapidly emerging R&D core competencies, as demonstrated by research funding, publication concentrations, IP generation, and other relevant metrics.
- They should have either an established base of existing regional industries that can address platform opportunities or have an observable and growing base of entrepreneurial businesses within the region.
- They should address large-scale, fast-growing markets, in traded industry sectors (providing an opportunity to significantly expand regional GDP).

Both recommended platforms demonstrate these characteristics. Furthermore, they represent disruptive technologies—areas driven by the application of novel technologies and paradigms that have the potential to shake-up existing industries and challenge the established industrial status quo. They present distinctive and large-scale opportunities for the Pittsburgh region to build upon its multiple assets and diverse R&D core competencies to establish a highly marketable position in new revolutionary industry sectors.

It is also notable that the platforms leverage the phenomenon of “convergence,” whereby multiple R&D strengths and disciplines converge to enable new perspectives and enable collaborations between institutions and research teams (Figure 10). This is most notable in terms of the convergence of biology and data sciences as well as the convergence of physical devices and data to enable the emergence of smart systems. The region’s diverse core competencies provide the potential to advance powerful and disruptive opportunities rooted in fundamental and applied biological sciences, clinical expertise, computational sciences, advanced analytics (including AI and machine learning), health Internet of Things (IoT), device engineering and robotics, automation science, cybersecurity, and more. Each of these is an individual strength that may be integrated with others (converged) to create signature opportunities (platforms) that will be challenging for other regions to duplicate.

Figure 10: Advanced Analytics at the Convergence of Data-Driven Healthcare and Next-Generation Therapeutics



Source: TEconomy Partners, LLC

The details regarding each of the four strategic opportunity areas (strategies) and their subsequent actions are outlined in the narrative that follows.

Strategy 1: Advance a signature platform in data-driven healthcare and connected devices.

Rationale:

The convergence of AI and advanced data sciences with healthcare and life sciences provides an opportunity rich environment for innovation. The combination of data-driven healthcare and connected devices represents a broad platform with opportunities to advance AI-driven biological innovations, smart healthcare, and connected health IoT devices. Importantly, barriers to commercialization are lower than in other health and life sciences product domains, and the Pittsburgh region has an opportunity to leverage its signature assets to attract inward investment.

Research Strengths in Data-Driven Healthcare and Connected Devices

The Pittsburgh region is well-positioned in the “convergence” of bioscience, healthcare, and digital/data sciences. As home to UPMC and AHN-Highmark, the region is the base for two of the largest integrated health systems in the nation—systems with deep clinical expertise, a very large base of patients, and robust data assets around patient health records, test results, tissue samples, health outcomes, and more. The fact that both AHN-Highmark and UPMC have integrated insurance operations provides further perspectives of considerable value. Having just one of these systems would make for a notable asset but having two leads the region to being particularly well resourced, enabling the region to potentially emerge as a national leader in encouraging innovation across both bio- and health-informatics. Data-driven healthcare was noted by AHN-Highmark to be a core focus of its research and internal development efforts moving forward, and UPMC and UPMC Enterprises have a major focus on this space. It is a dynamic sector development opportunity that carries multiple economic development benefits:

- It can make healthcare more efficient, cost effective, personalized, and precise thereby optimizing the use of healthcare funds within the region and improving healthcare productivity.
- It presents multiple pathways to commercial innovations in healthcare management systems, hybrid smart systems, and digital and remote health solutions.
- It presents opportunities to advance novel and improved therapeutics rooted in data-driven insights.

A signature asset for the Pittsburgh region in data sciences and associated disciplines is the presence of CMU. Recent rankings from *U.S. News and World Report* highlight CMU’s top-ranked programs in AI, cybersecurity, software engineering, mobile applications, management information systems, and computer engineering.¹⁶ An analysis of academic R&D finds that computer sciences are the region’s “secret sauce,” representing its most specialized R&D field (with a concentration roughly four times that

16 <https://www.cmu.edu/about/rankings.html>

of the nation).¹⁷ It is also the region's fastest growing field (experiencing 49 percent growth in R&D since 2018). Alone, CMU is a powerful asset. However, when combined with the world-class academic medical center at Pitt and other key assets, including AHN-Highmark and the current base of life sciences and medical device companies, the opportunities for convergence based, disruptive innovations and industry growth have the potential to be transformational.

From 2018-2023, Pittsburgh received \$34 million in NIH funding from the National Library of Medicine (NLM), which is responsible for supporting research in medical language processing, high-speed access to bio-medical information, analysis and use of high-quality biomedical imaging data, and large-scale analysis of clinical and administrative data to predict patient outcomes.¹⁸ While this represents a small share of the total NIH funding in the region (less than 1 percent of the total), the region is highly specialized: NLM funding is 3.2 times as concentrated in the region compared to the nation. This suggests that the NLM, the nation's foremost funder of data-driven healthcare, looks to the Pittsburgh region as a research leader.

Within the Pittsburgh region, there are multiple distinctive signature assets that are, or could be, focused to advance a data-driven healthcare platform. This begins with the comprehensive clinical and claims data that resides in the region's two integrated delivery and finance networks. In addition, Pittsburgh is home to a robust set of biorepositories that provide a distinctive biological data set. Unique facilities and capabilities at the region's research-intensive universities bring together technical expertise with specific aspects of data-driven healthcare platform. Finally, the Pittsburgh region is home to several specialized programs in which significant investments have been made to provide noteworthy capabilities related to data-driven healthcare.

One signature asset is UPMCE Digital Solutions, which develops and invests in innovative healthcare technologies by providing strategic, technical, and financial support. By offering a dynamic testing environment, UPMCE Digital Solutions helps to validate and refine healthcare products through pilot programs and market assessments. Examples of UPMCE activities include developing telemedicine services that streamline communication between providers, such as Infectious Disease Connect (which allows hospitals to consult with infectious disease experts in real-time, resulting in better and faster care for patients) and Safar TeleCare (a web-based application that eliminates the need for complex call center routing by connecting bedside providers with specialists anywhere within UPMC). UPMCE also develops products that enable patient engagement through programs like UPMC Rx Express (which helps make prescription refills and medication adherence convenient and easy) and Pip Care (a consumer-facing app that helps patients prepare for and recover from surgery).

Another signature asset of the region is the CMU CloudLab: a 24/7/365 remote-access facility with over 200 scientific instruments that provide full control over laboratory processes, data inputs, outputs and sharing. All processes are fully traceable, end-to-end and enhanced with auxiliary sensor data and

¹⁷ TEconomy's analysis of NSF HERD Data

¹⁸ TEconomy's analysis of NIH award data

sample/asset tracing, creating rich and comprehensive datasets that allow investigators to utilize more than 4,500 powerful functions for data visualization, analysis and simulation.

Beyond CloudLab and UPMCE Digital Solutions, additional assets for data-driven healthcare exist across the region. The following is not an exhaustive list, but it is illustrative of both the breadth and depth of intellectual horsepower and academic infrastructure assets (Figure 11 and Figure 12).

Figure 11: Data-Driven Healthcare – CMU Assets Table

Department of Computational Biology

The Ray and Stephanie Lane Computational Biology Department at CMU combines world-class strengths in computer sciences and biology to offer interdisciplinary training and globally recognized research. CMU ranks 1st in the world in Computational Biology and Bioinformatics (according to CSRankings), and 3rd overall in Biocomputing and Bioinformatics, according to US News and World Report. Notable research strengths of the department include biological modeling, genomics, machine learning applications in biology, algorithmic development for biological data analysis, and the integration of computational approaches to solve complex biological problems (e.g., genetics, drug discovery and design, and systems biology).

Center for Machine Learning and Health

As part of the CMU School of Computer Science, this center is a hub for interdisciplinary research focused on innovative digital health solutions that improve healthcare delivery, outcomes, and cost-effectiveness. This center has notable research strengths in applying machine learning, artificial intelligence, and other computational approaches to healthcare challenges, with a particular emphasis on consumer-oriented healthcare and healthcare infrastructure efficiencies.

Center for Innovation in Health

As another part of the CMU School of Computer Science, this interdisciplinary research center focuses on advancing digital health technologies. Research strengths of the center include digital bioscience and informatics, AI-driven healthcare analytics, public health forecasting, medical robotics, telehealth, and other clinical care technologies.

CYLAB – Security and Privacy Institute

A world-renowned research center focused on developing innovative cybersecurity and privacy solutions. Strengths of this center include software and network security, threat analysis and modeling, cryptography, usable privacy/security, and the intersection of AI/ML with security.

Pittsburgh Robotics Institute

Established in 1979, this preeminent research center is dedicated to advancing robotics research and education. With strengths across industrial robotics, computer vision, artificial intelligence, and autonomous systems development, this is the largest university-affiliated robotics organization in the world. Through its Medical Robotics Technology Center (MRTC), the institute develops innovative technologies such as computer-assisted surgical systems, rehabilitation devices, smart medical tools, and other robotic systems that help enhance healthcare delivery and improve patient outcomes.

National Robotics Engineering Center

The National Robotics Engineering Center has made significant contributions to healthcare and life sciences through advanced computer vision and robotics technologies. Their innovations include a drug discovery system that automates behavioral observations for identifying promising compounds; a medical image registration system that achieves sub-millimeter accuracy in patient positioning for radiotherapy; computer vision algorithm to monitor patients in clinical trials for spinal therapies; and an intelligent portable electrocardiogram (ECG) that can automatically diagnose arrhythmias that could lead to sudden cardiac death (SCD).

The Delphi Center

Founded in 2012, this group focuses on developing epidemiological forecasting technologies to aid decision-making in public health and other sectors. The group aims to make epidemic forecasting as reliable and widely used as weather forecasting, with current projects targeting diseases like influenza and dengue.

AI Institute for Societal Decision Making

CMU is leading the AI Institute for Societal Decision Making, a five-year, \$20 million initiative funded by the NSF. The institute brings together AI researchers and social scientists to develop human-centric AI tools that will help professionals in fields like public health and emergency management make better decisions under complex and uncertain conditions.

Department of Biomedical Engineering

CMU is renowned for its cutting-edge research in areas like neural engineering, biomaterials, and computational biology, consistently ranking among the top programs nationally. The department offers a unique additional major program that combines rigorous engineering education with biomedical sciences, leveraging collaborations across engineering departments and medical institutions in Pittsburgh. The department was recently part of a multi-institutional research team awarded \$45 million by ARPA-H to fast-track the development of new cancer implant technologies. Another CMU-led team has secured an award of up to \$42 million from ARPA-H to accelerate the development of implantable, cell-based bioelectronic devices that deliver patient-specific therapy and monitor disease status.

Figure 12: Data-Driven Healthcare – University of Pittsburgh (Pitt) Assets**Pitt Center for Healthcare Management**

The Center for Healthcare Management is a multi-disciplinary research institute that focuses on advancing healthcare delivery practices and improving outcomes. Strengths of the institute include healthcare management across private and public sectors, the development and implementation of health policies, and addressing challenges in healthcare delivery (e.g., value-based population health, care for patients with complex patients).

Pitt Center for Public Health Practice

The Center for Public Health Practice is committed to partnering with local, national and global practitioners to provide innovative public health practice experiences and policy research to improve population health for all communities.

Pitt Epidemiology Data Center

A multidisciplinary research hub that collaborates with clinical scientists across the world to manage complex clinical trials and epidemiological studies across domains such as aging, cardiovascular health, mental health, women's health, infectious diseases, and diabetes. The center also helps to develop and refine data collection, management, computing, and statistical methods around disease treatment.

Pitt Public Health Dynamics Laboratory

This unique interdisciplinary research center focuses on developing computational methods that improve public health theory and practice. This center has notable strengths in modeling of infectious diseases, spatial epidemiology, global public health databases, vaccine distribution, public health emergency responses, and open-source computational tools for analyzing complex public health issues.

Pitt/UPMC/CMU Health Data Alliance

The Health Data Alliance is a previous effort at a significant industry-university partnership involving UPMC, Pitt, and CMU. The initiative focuses on bringing forward data insights from clinical activities to improve diagnosis, enhance quality of care, and prevent diseases.

Other institutional assets exist across the region to support data-driven healthcare. Highmark Health is partnering with Verily to develop generative AI solutions aimed at optimizing care delivery and improving physician and patient experiences. This collaboration focuses on using Verily’s advanced AI capabilities to enhance the clinical and technological capabilities of Highmark, with potential applications around personalizing care and making more information accessible to providers. As part of this program, in 2024 AHN rolled out a large language model designed exclusively for use by its staff members and trained solely on AHN/Highmark’s own data. Other AHN/Highmark activities related to data-driven healthcare include:

- Highmark Health’s VITAL Innovation Program is a test-and-learn platform designed to accelerate the adoption of promising new healthcare technologies by providing real-world evidence on their effectiveness.¹⁹ The program allows Highmark Health to test early-stage FDA-approved innovations in clinical settings, generating data on patient experience, health outcomes, and cost impacts. This can potentially fast-track coverage and utilization by healthcare delivery systems.
- A partnership between AHN’s Research Institute and the Israeli Innovation Authority to provide healthcare startups with access to AHN facilities for pilot projects, advanced technology support, and other forms of program assistance.²⁰
- The Disruptive Health Technology Institute (DHTI) was established as a collaboration between AHN/Highmark and CMU to test and deliver disruptive healthcare innovations.²¹ The DHTI utilizes de-identified, aggregated claims data from Highmark to support research and develop new healthcare solutions. Since 2013, DHTI has invested \$5 million in 38 projects led by CMU researchers who are working with industry, payers, and providers striving to create disruptive healthcare solutions.

Elsewhere, the Biomedical Applications Group pursues collaboration between Pittsburgh Supercomputing Center experts in computational science and biomedical researchers nationwide. Scientists in this group develop computational methods and tools and conduct research on biomedical systems at the cell and tissue level with a focus on neural systems, such as the brain and the central nervous system.

The Pittsburgh region is also a leader in the production of data-driven healthcare degrees: an analysis of IPEDS data finds that, from bachelor’s through doctoral degrees, the Pittsburgh region is seeing growth in data-driven healthcare degrees at rates faster than the U.S.²² Data-driven healthcare degrees in the region increased 138 percent from 2018-2023, growing from 82 data-driven healthcare degrees in 2018 to 195 degrees in 2023. The regional growth in these programs exceeds the nation (57 percent growth) and all benchmarks studied.

19 <https://www.ahn.org/health-care-professionals/research/our-partners/highmark-vital>

20 <https://www.prweb.com/releases/alleggheny-health-network-israel-innovation-authority-announce-plans-for-technology-start-up-collaboration-882057280.html>

21 <https://www.ahn.org/health-care-professionals/research/our-partners/dhti>

22 TEconomy’s analysis of NCES IPEDS data. Data-Driven Healthcare Degrees Include: Bioinformatics, Biomathematics, Biostatistics, Cheminformatics, Computational Biology, Epidemiology and Biostatistics, Informatics, and Medical Informatics.

Connected Devices

As a subset of the data-driven healthcare platform, connected devices leverage the regional specialization in medical devices with other life sciences, engineering, and computational core competencies. Connected devices refer to advancements in implantable, wearable, and other device forms that interface between biological and electronic or mechanical systems. This may include devices such as neurostimulation devices, drug/therapeutic smart delivery systems, sensor and monitoring/alert systems, automated/remote intervention delivery, secure connectivity to health providers, etc.

Pittsburgh is home to a substantial existing base of connected medical device manufacturers, including divisions of Zoll, Haemonetics, Smith & Nephew and Bayer's medical devices. The device industry is moving rapidly from stand-alone devices to connected devices that integrate software and hardware and collect and export data. As an example, Smith & Nephew's CORI Surgical System combines handheld robotics with digital surgery applications. The ZOLL LifeVest, a wearable defibrillator manufactured in the region, can automatically detect life-threatening heart rhythms and deliver treatment shocks and serves as another example of the connected devices strength in the region.

Pittsburgh's research universities are also home to numerous R&D labs and specialized facilities that can help encourage the connected devices sector (Figure 13).

Figure 13: Connected Devices – Institutional Regional Assets (University of Pittsburgh and Carnegie Mellon University)

Pitt Center for Assistive Technologies

This Center is a collaborative program between Pitt and UPMC that provides solutions for individuals with disabilities who need assistive technologies for mobility, hearing, speech, and other everyday needs. The strengths of the institute lie in developing and improving assistive devices and leveraging interdisciplinary expertise from engineers, physicians, therapists, and rehab specialists to create cutting-edge new technologies.

Pitt Center for Bioengineering

The Center for Bioengineering is a segment of the Department of Bioengineering at Pitt that houses multiple multidisciplinary labs that both provide courses to undergraduate students and lab space to research teams. The labs housed at The Center include a musculoskeletal research center, a bio-transport lab, an orthopedic robotics lab, a computational biomechanics lab, and a vascular bioengineering lab.

Pitt Center for Biological Imaging

The Center for Biologic Imaging provides integrated imaging access and training for research, education, and the development of technology in microscopy, biophotonics, and imaging. The Center also provides information on mounting medias, stains, and stock solutions, as well as training guides for their microscopes, analysis computers, slide scanners, and many other imaging equipment.

Pitt Center for Image Guided Neurosurgery

The Center for Image-Guided Neurosurgery combines multiple neuroscience-related disciplines, including neurosurgical oncology, stereotactic radiosurgery, and neuroradiology. The Center has become a leader in several innovative technologies, including MEG brain imaging, minimally invasive Gamma Knife treatment, and an ultrasound-based tumor therapy.

Pitt Center for Medical Innovation

The Center for Medical Innovation is a collaborative organization that partners with the Swanson School of Engineering, the Innovation Institute, and other academic entities to sponsor teams of clinical researchers and engineers seeking commercialization for their medical development projects. Since 2011, the CMI has supported, through seed grants and advisory services, 37 early-stage projects, as well as developed curriculum for a Master of Science in Bioengineering degree program.

Pitt Neuromuscular Research Laboratory and Warrior Human Performance

The Neuromuscular Research Laboratory is an applied research facility within Pitt's School of Health and Rehabilitation Sciences that conducts research on proprioception, neuromuscular control, and musculoskeletal injuries and pathologies. The Laboratory also works with the U.S. government, providing injury prevention and performance enhancement models to the military as well as administrative oversight to the DoD.

Pitt Human Engineering Research Lab

The Human Engineering Research Lab is part of the U.S. Department of Veterans Affairs that is developing and researching different areas of mobility support, including assistive robotics, wheelchairs, and rehabilitation. The Lab additionally works with international organizations like WHO and ISO to produce and design wheelchairs for different levels of disability, different levels of available resources, and for international wellness programs.

CMU College of Engineering – Medical Devices and Robotics

Within the College of Engineering, the Biomedical Engineering program within CMU focuses on Medical Devices & Robotics. In particular, research leverages the school's expertise in systems engineering, computation, and robotics to develop innovative new technologies across topics like neural engineering, cardiovascular mechanics, and surgical devices. Other research areas include biomaterials, biomechanics, and biomedical imaging.

CMU Neuroscience Institute

The Neuroscience Institute conducts research on brain functions to better understand healthy brains and treat diseased brains, including the development of robotic prosthetics, visualization models, and implantable devices. Their research focuses include cognitive neuroscience, computational neuroscience, neural engineering and technology, and systems neuroscience.

Industry Strengths in Data-Driven Healthcare and Connected Devices

The Pittsburgh region is home to multiple companies involved in data-driven healthcare and connected devices (Figure 14). Together, these companies employ thousands of individuals in the region and are actively advancing human health innovation. Many of the region's leading employers in the life sciences are focused on data-driven healthcare and connected devices, including firms such as Philips Respironics (2,000 employees; 275 Regional Patents), Zoll LifeVest (1,300 employees; 163 Regional Patents), Bayer (1,400 employees; 132 Regional Patents), Omnicell (500 employees; 24 Regional Patents), TeleTracking (484 employees; 80 Regional Patents), and Smith & Nephew Robotics (200 employees; 60 Regional Patents). Other leading companies include Abridge, with more than \$150 million in venture capital raised.

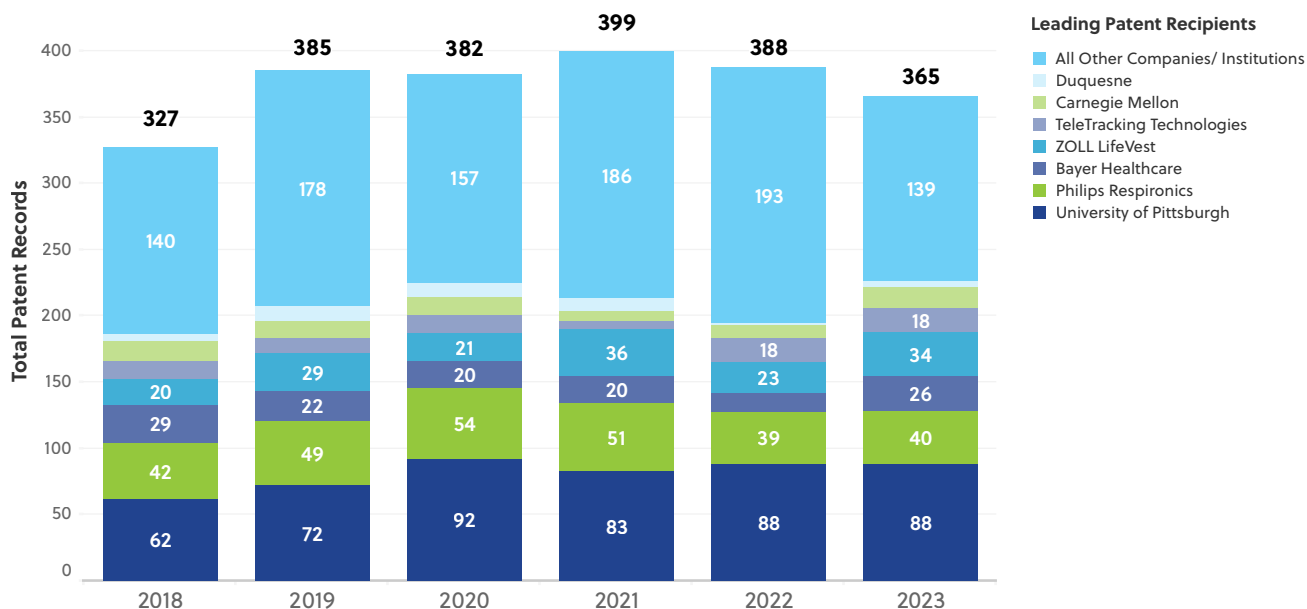
Figure 14: Examples of Companies in Data-Driven Healthcare and Connected Devices



Source: TEconomy Partners, LLC

Companies in the data-driven healthcare and connected devices industry are driving patent activity in the region. TEconomy identified 2,246 patents granted in life sciences-related fields with inventors based in the Pittsburgh region, and of these, the majority were in areas related to devices. Philips Respironics, Bayer Healthcare, and ZOLL LifeVest represent the leading companies for patents in the Pittsburgh region. Together, these three companies represented 25 percent of all life sciences patents in the region since 2018 (Figure 15). Healthcare informatics (i.e., information and communication technology specifically adapted for the handling and processing of healthcare data and medical data) represents 7 percent of all life sciences patent activity in the region (153 total patents since 2018).²³ While this may seem like a small figure, informatics and other information technologies are not generally patented due to a variety of reasons. Still, informatics patents represent a noticeable portion of patent activity for leading companies like TeleTracking (25 percent of their total patents in the region), Zoll (9 percent of their total patents), Bayer (11 percent of their total patents), and Philips Respironics (4 percent of their total patents). This suggests that many of the medical devices companies in the region are not only leaders in the development of new products, but also new software systems that connect to these devices.

Figure 15: Life Sciences Patents Granted in Pittsburgh Region by Year



Source: TEconomy’s analysis of data Derwent Innovation USPTO Data

23 TEconomy’s analysis of data Derwent Innovation USPTO Data

Data-driven healthcare companies have also been successful in raising venture capital. An analysis of Pitchbook data finds 74 deals to startups since 2018 focused on healthcare technology systems, totaling \$281.2 million in funding.²⁴ Further, there were 51 deals to digital health and health tech companies accounting for \$74.3 million. Healthcare devices and supplies companies are also receiving considerable venture capital, raising a total of \$141 million since 2018 across 89 deals. The region’s concentration of deals in the devices industry is 19 percent higher than the nation. However, several medical devices companies have struggled to gain traction beyond their initial VC raise for a variety of reasons, consistent with the challenges of raising capital in the region that were articulated in interviews and focus groups.

The data-driven healthcare and connected devices platform represents a significant market opportunity for the Pittsburgh region (Figure 16). BCC Research market data finds that the digital healthcare global market is projected to reach nearly \$385 billion in 2026 and grow at an estimated 17 percent CAGR during the 2021-2026 forecast period. Meanwhile, the smart medical devices segment should reach more than \$122.8 billion in 2026, with a CAGR of 16.8 percent during the forecast period of 2021-2026. Bioinformatics is a somewhat smaller but still sizable opportunity, projected to grow 14 percent during the 2023-2028 forecast period to reach \$35.5 billion in global market size. Combined, these three sectors represent over a one-half trillion-dollar market space.

Figure 16: Projected Global Markets for Data-Driven Healthcare and Connected Devices Platform

Platform	Projected 2026/2028 Market Size (\$,Billions)	CAGR*	
Data-Driven Healthcare and Connected Devices	Digital Health	\$384.8	17%
	Smart Medical Devices	\$122.8	17%
	Bioinformatics	\$35.5	14%

Source: TEconomy’s analysis of BCC Research

To help ensure that the Pittsburgh region is well-positioned to capture a portion of this market, it is recommended that the region pursue three strategic actions to help advance a signature platform in data-driven healthcare and connected devices:

- Action 1.1: Build a dominant position in data-driven healthcare innovation.
- Action 1.2: Advance programs for health systems to provide a “voice of customer” to industry and academia.
- Action 1.3: Connect, grow, and retain region’s connected device industry.

24 TEconomy’s analysis of Pitchbook data

Action 1.1: Build a dominant position in data-driven healthcare innovation.

The Pittsburgh region benefits from a potentially unmatched alignment of signature data-driven health assets—large-scale, data-rich health systems, a top tier academic medical center, major health insurance organizations, the number one ranked university in AI and in multiple areas of advanced analytics, and a growing base of digital health companies and medical device companies engaged in connected devices. Rarely does a region have so many assets to bring to bear for staking a leading position within a rapidly growing, disruptive, \$500+ billion global marketplace. The opportunity is extremely large and the assets to work with are quite distinctive. When this alignment of competencies has occurred before (i.e., in software engineering, robotics, advanced manufacturing, and supercomputing), the Pittsburgh region has been able to establish or attract a major, signature initiative to leverage and coordinate its assets to pursue significant opportunities. Investment in a collaborative, multi-institutional, multi-disciplinary initiative for data-driven healthcare will provide the region with a hub for convening a broad range of stakeholders, researchers, and innovators and facilitating collaborative projects.

It is recommended that the Pittsburgh region develop a specific planning initiative around data-driven healthcare that explores where and how to best promote strengths, utilize activities underway, and fill in gaps for the platform. Bringing together multiple stakeholders, researchers, and innovators under a joint initiative for data-driven healthcare could offer several significant benefits:

- **Synergy of expertise:** By bringing together academic institutions (Pitt and CMU), healthcare providers (both large scale such as UPMC and AHN as well as independent rural systems such as IRMC and Heritage Valley), insurers (Highmark and UPMC Health Plan), and business ventures (of all sizes), the initiative could create a powerful synergy of diverse expertise. This collaboration could foster interdisciplinary research and innovation, combining medical knowledge with cutting-edge technology and business acumen.
- **Improved data integration:** A joint initiative could work on standardizing data formats and developing interoperable systems, addressing one of the key challenges in healthcare data management. The partnership could support healthcare systems—who have access to extensive medical records and patient data—with the development, validation, and integration of AI/ML and other data-driven approaches in healthcare.
- **Accelerated innovation and implementation:** The close collaboration between academia, industry, and healthcare providers would streamline the process of translating research into practical applications. This would speed up the development and adoption of new technologies and methodologies in clinical settings.
- **Attraction of talent and investment:** A multi-institutional initiative would position the region as a leading hub for digital health innovation, attracting top talent, researchers, and entrepreneurs to the region. This concentration of expertise would, in turn, attract more investment and business opportunities.

- **Improved patient outcomes:** By leveraging the combined resources and expertise of multiple institutions, the initiative could develop more effective, personalized, and efficient healthcare solutions, ultimately leading to better patient outcomes.
- **Improved health system efficiency:** the initiative could develop solutions to advance health system productivity, efficiency, and cost-reduction while sustaining quality patient-focused care.
- **Improved marketability:** Having a central identity for the region’s multiple assets in data-driven healthcare will make it easier to raise awareness of collective strengths with external parties and funders.

Potential Action Components:

Three macro areas of focus are recommended for integration within a Pittsburgh region data-driven healthcare initiative:

- **Health Information and Informatics:** Advancing innovations in the use of advanced analytics to improve healthcare practices, processes, operations, efficiency, and improve outcomes.
- **Connected Devices:** Building upon academic strengths and industry presence in devices to advance smart, connected (health IoT), and physical AI devices (such as implants, wearables, assistive devices, etc.)
- **Bioinformatics/Computational Biology:** Integrating strengths in advanced analytics and computational biology, applied to health system data to drive discovery science for innovations in diagnostics, biomarkers, therapeutics, and biomolecules. This should incorporate the close engagement of leading academic medical programs with clinical research excellence.

A data-driven healthcare initiative would leverage multiple signature assets in the region:

- Two very large health systems with integrated insurance systems, providing an intensive and extensive data-rich environment.
- Integrated health systems prioritizing and investing in the sector, providing opportunities for piloting and first-customer.
- The presence of the top ranked university (CMU) in AI, machine learning, machine vision, and computational biology, together with complementary advanced capabilities at Pitt.
- An existing cluster of emerging companies in the Pittsburgh region, together with larger companies that produce connected devices.

There certainly exists no shortage of challenges, needs, and opportunities for the envisioned initiative to address. Some examples of areas in which a collaborative initiative could make important advancements are highlighted in Table 3.

Table 3: Select Areas Where Pittsburgh is Well-Suited to Advance Data-Driven Healthcare and Associated Innovation

Potential Activity	Focus and Benefits
Establishing a shared high-performance computing infrastructure	Providing researchers and clinicians with access to powerful computational resources for processing and analyzing large-scale health data.
Creating standardized data sharing protocols	Developing secure and efficient methods for sharing medical and health system data across institutions while maintaining patient privacy and regulatory compliance.
Development of advanced AI and machine learning models	Creation of cutting-edge algorithms and models for disease prediction, personalized treatment plans, drug discovery, and improved health system operations using the vast datasets available.
Conducting large-scale clinical trials	Leveraging the combined patient populations of participating healthcare systems to conduct more comprehensive and diverse clinical trials for new treatments and technologies.
Creating a living laboratory for digital health	Facilitating the implementation and testing of new technologies and methodologies in real-world clinical settings across the participating healthcare systems. This would also include collaborations with rural health providers and organizations across the region.
Incubating and accelerating digital health startups	Providing expertise and resources, mentorship, and access to clinical environments for testing and validating new digital health solutions.
Establishing and operating training programs	Developing interdisciplinary educational programs to train the next generation of healthcare professionals, data scientists, and entrepreneurs in digital health innovation.
Collaborations in policy development	Working with regulatory bodies to shape policies that support innovation in digital health while ensuring patient safety and data privacy.

Best Practices: QB3

The California Institute for Quantitative Biosciences (QB3), established in 2000 as a partnership between the University of California system, state government, and industry is an example of how academic strengths can be leveraged to create a focused innovation ecosystem to attract major corporate partners.²⁵ QB3 serves as a network to an array of basic research centers at the cutting edge of quantitative biosciences, involving cell imaging, biocomputing and visualization, small molecule discovery, synthetic biology and cell engineering, among others. It has developed a range of support for entrepreneurs including a network of incubators, a venture capital fund, entrepreneurial support programs, SBIR/STTR workshops, and non-dilutive funding. With five incubators, two seed-stage venture capital firms, and a special initiative in medical devices, QB3 helps bio-entrepreneurs create high-value jobs and attracts more than \$750 million into the Bay Area each year. QB3 also has a strong history in advancing strategic research alliances, including with Pfizer, Johnson & Johnson and GE Healthcare.

Steps for consideration in planning a data-driven healthcare initiative

Data-driven healthcare is a broad space with many potential opportunities. Stakeholders in the Pittsburgh region will need to identify the areas of greatest potential opportunity, where new collaborations can unlock major leaps in innovation. A first step in this process is close listening to the voice of customer (industry, government, etc.) to identify areas of focus.

The universities in Pittsburgh have direct experience in standing-up collaborative research centers and institutes and that experience and expertise should obviously be brought to bear on planning for the development of a data-driven healthcare initiative. Based on the opportunities identified through the voice of customer listening and collaboration process, a potential pathway to follow could include:

1. The senior leadership of key stakeholder organizations would be convened to achieve high level commitment to development of a shared data-driven healthcare initiative. This would require participation by the leadership of Pitt, UPMC, AHN-Highmark, and CMU.
2. Leveraging the commitment and this strategic opportunity analysis, the Commonwealth of Pennsylvania should be approached to secure a planning grant, with matching institutional and/or philanthropic funding, to develop a study comprising:
 - a. Mission and vision statement for the initiative, and description of envisioned institutional objectives, and envisioned outcomes or returns on investment.
 - b. Alignment with regional and state economic competitiveness and national security priorities.
 - c. Initial identification of research and innovation themes and potential projects.
 - d. A profile of researchers, research teams, and industry groups to engage in the initiative.
 - e. A staffing, leadership, and governance model for the initiative.
 - f. A timeline for initiative development.
 - g. Outline of resources needed to meet objectives and creation of a draft budget and funding model.
3. Use the planning study to secure funding (i.e., state, federal, philanthropic, and industry sources).

25 <https://qb3.org>

It should be noted that it is not anticipated that development of a data-driven healthcare initiative would require the type of funding scale deployed for BioForge (which required development of GMP/GLP quality space and equipment with advanced manufacturing technologies). For a data-driven healthcare initiative with a physical footprint, the main expenses beyond labor and operations would be for a building to house the initiative and the establishment of state-of-the-art computing and storage resources. A rough budget estimate for such a center could be circa \$50 million for facilities, equipment, computation and storage cluster development, and associated costs (e.g., software acquisition and licensing, data acquisition, compliance, and cybersecurity systems, etc.) If the region were to pursue an institute model, costs for staffing and annual operating costs for a fully built out initiative could exceed \$15 million, depending on the final scale of the effort and the amount of funding available for translational research projects. A smaller-scale initiative would have a smaller annual operating budget.

Action 1.2: Advance programs for health systems to provide a “voice of customer” to industry and academia.

As a leading region for major healthcare system operations, comprehensive healthcare provision, and integrated health insurance operations, together with smaller regional hospitals and health systems, the Pittsburgh region provides the full spectrum of institutions and operations encountered in the American healthcare environment. As a result, there are a wealth of practitioner observations regarding ways to improve healthcare delivery whose potential solutions are rooted in digital healthcare. Companies and innovators in data-driven healthcare will benefit greatly if they are able to receive active intelligence from the regional healthcare system. Such an intelligence flow would also be beneficial to identifying strategic areas for activities at the envisioned data-driven healthcare initiative (Action 1.1).

Several areas were identified that the Pittsburgh region is well suited to explore, including:

- **Rural Health:** Testing and implementing new technologies in collaboration with rural health providers and organizations across the 10-county region, such as Indiana Regional Medical Center and other healthcare systems with a presence in the region. Data-driven healthcare has the potential to generate impacts across the region with both innovation and job opportunities. A focus on this platform can help benefit the region’s outlying areas by providing these communities with world-class advancements in precision medicine, predictive health interventions, and expanded telehealth services. Health systems will also provide new job opportunities in these communities, from health IT specialists to community health workers and administrators.
- **Aging:** Managing the cost and continuum of care across the region’s aging population is a long-standing concern, but there is potential to find solutions to aging-related healthcare concerns via digital technologies.
- **Cybersecurity:** The implementation of digital health solutions requires a high-level of attention be paid to cybersecurity (in the storage and analysis of patient data, and in security across the networks of connected devices increasingly deployed in healthcare provision). The region is well-equipped with expertise in cybersecurity to address critical areas of need.



Similarly, the Pittsburgh region could be an excellent location for large V&V (verification & validation) efforts of novel digital platforms, given the socioeconomic and geographic distribution of patients and the range of health system delivery providers.

Potential Action Components:

- Conducting “listening sessions” with leadership across the 10-county region’s health systems to identify areas of priority, inform planning for a data-driven healthcare initiative (Action 1.1), and explore potential areas of focus for a “voice of customer” pilot program.
- Developing a mechanism for the reporting of identified needs and challenges into the data-driven healthcare initiative and to participating industry stakeholders. This will likely need institutional gatekeepers in the health systems to ensure that the challenges or issues relayed do not contain sensitive or regulated information.
- Leveraging Action 1.1 and the expertise of region’s large healthcare systems and smaller rural hospital systems to develop a testbed for companies and innovators to access as they work to advance data-driven healthcare and connected devices technologies. Example areas of activity could include telemedicine, remote patient monitoring technologies, and patient enablement.
- Identification of high need applications/use cases in data-driven healthcare and remote monitoring, with a focus on better support for the region’s rural and elderly/aging populations.
- Providing a testbed and relevant support for regional vendors and providers to experiment with new technologies and approaches, and capturing lessons learned for input into regional population health planning and patient management.
- Establishing relevant startup support programming to identify and grow entrepreneurial solutions to pressing challenges such as cybersecurity and aging care.

Pittsburgh's Supercomputing Center: A Unique Capability for Studying Aging

At the Pittsburgh Supercomputing Center (PSC), the Biomedical Applications Group conducts cutting-edge research in high performance computing in the biomedical sciences. Researchers are developing new computational models, methods, and tools to conduct research on biomedical systems at the cell and tissue level with a focus on the brain and the central nervous system.²⁶ Current projects and collaborations include:

- **Brain Image Library (BIL):** A national public resource and collaboration with CMU's Molecular Biosensor and Imaging Center and Pitt's Center for Biologic Imaging that enables researchers to deposit, analyze, mine, share, and interact with large brain-image datasets.
- **The Human BioMolecular Atlas Program (HuBMAP):** A mapping system for human tissues funded by NIH is a collaboration between PSC and the Department of Biomedical Informatics (DBMI) at the Pitt School of Medicine. PSC and DBMI are working with a number of other teams as part of the HuBMAP Integration, Visualization, and Engagement (HIVE) Collaboratory.
- **The Cellular Senescence Network (SenNet):** Through coordination by scientists in Pittsburgh, SenNet will create navigable, 3D maps of the body that offer data and analysis on cellular aging, shedding light on nerve degeneration, diabetes, cancer, and normal tissue functions. This program is funded by the NIH Common Fund and overseen in collaboration with the National Institute on Aging and National Cancer Institute.

Action 1.3: Connect, grow, and retain region's connected device industry.

As previously noted, the Pittsburgh region's medical device industry sector is 80% more specialized in employment when compared to the nation. Led by companies like Zoll, Haemonetics, Smith & Nephew, Bayer, and others, the Pittsburgh region has a history of device development and manufacturing innovation, encompassing a diversity of device types. As a manufacturing-intensive industry, the medical devices subsector employs nearly 5,800 workers across the region in a variety of roles, from R&D to manufacturing production to quality assurance to sales and marketing.

For the most part, the region's companies in the device space are not competing with one another in the same field—although there are some shared characteristics, one of which is a need to navigate the increasing digital connectivity of devices deployed in healthcare and the issues associated with that in terms of analytics, actionable insights, and cybersecurity. These shared issues provide an impetus for collaborative projects between industry and the data-driven healthcare initiative.

There is considerable sophistication in the IT operations of hospitals and health systems, and within connected device companies. Where challenges are likely to occur are at the intersection of the patient and the device in outpatient care settings—the home, workplace, or other non-healthcare environments.

26 <https://www.psc.edu/biomedical-applications/>

What is emerging is a healthcare Internet-of-Things (also known as the Internet of Medical Things or IoMT) over which a multiplicity of devices communicate—some in quite secure hospital or health system settings, but others that rely on access over public networks, home data networks, wireless systems, or local Bluetooth communications where security, data integrity, and reliability issues are introduced.

What is evolving is a network of Internet-connected medical devices, hardware infrastructure, and software applications used to connect healthcare information technology. It enables the collection, transmission, and analysis of health-related data from medical devices and sensors to healthcare IT systems over internet networks, without requiring human-to-human or human-to-computer interaction. Including devices like wearables, smart bands, digital medications, implantable surgical devices, CPAP machines, and other portable health monitoring devices. IoMT technologies run the gamut from routine data collection through to management of real time critical medical events. Connected devices facilitate remote patient monitoring, real-time health tracking, early disease detection, and data-driven decision making in healthcare, and a goal of their deployment is to improve healthcare delivery, patient outcomes, and operational efficiency in healthcare systems.

Increasingly, connected devices integrate with other technologies like AI, machine learning, and data analytics to provide insights from the collected health data. Into the future, devices are likely to be proactive in terms of using data to specifically manage and provide clinical actions. Ultimately, connected devices will be transformative in medical care by enabling more proactive, continuous, and coordinated health management both inside and outside traditional healthcare settings. The journey to get there, however, requires multiple barriers and challenges be addressed, which in turn represents opportunities for R&D and innovation through the data-driven healthcare platform.

Potential Action Components:

- Build on and connect the region’s significant device industry (many of these incorporating electronics and data generation) by convening industry parties and other stakeholders to discuss and align across shared interests.
- Establish a centralized innovation initiative alongside Action 1.1 that brings together medical device companies, healthcare providers, academics, and AI experts to focus on such areas as the impacts and applications of AI in connected devices, data access, storage and analytics, and cybersecurity.
- Explore opportunities to leverage and learn from regional strengths in robotics and autonomous systems where there are complementary concerns in terms of data transfer, real-time decision making, cybersecurity, data integrity, networking systems, and evaluation of edge cases. Another area of expertise to leverage is assistive technologies—how to interface devices and persons with various ability levels. More broadly, there is expertise in the region in human-machine interfaces and design of accessible systems.

- Gather industry insights on needs for education and training programs to prepare talent to meet the needs of a connected device industry in the region. Work to develop a core curriculum or individual stackable credentials that will meet the majority of needs.

It is likely that the connected medical devices and IoMT solutions that reach the market will have a series of characteristics, each of which presents opportunities for the data-driven healthcare platform. These may include:

- Interoperability and data integration that enables devices to easily, and securely, connect and share data with other systems and platforms—including connectivity to existing healthcare IT ecosystems.
- Advanced data analytics capabilities, including the incorporation of AI and machine learning for predictive analytics and, potentially, real-time decision making.
- Systems and approaches to appropriately manage large volumes of real-time patient data in central, cloud, edge, and individual device environments.
- Data protection and privacy, including data protection and management protocols and cyber security technologies.
- Ability to comply with current and future healthcare data regulations.
- Remote monitoring and telemedicine functionalities, including real-time data transmission to healthcare providers, support for remote patient monitoring, and virtual care delivery.
- User-friendly interfaces and intuitive design features that meet the needs of both patients and healthcare professionals, prevent errors, and encourage compliance.
- Customizable features to meet individual patient needs, enabling personalization and adaptability based on patient data and usage patterns.
- Provide advantages in terms of early detection and alerts for potential, emerging, or current health issues.
- Provision of AI-based or other proactive recommendations for health management
- Cost effectiveness versus other care options, together with evidence of clinical efficacy.
- Demonstrated reliability and ease of maintenance and remote troubleshooting.
- Flexible architecture to accommodate future technological or application advancements and remote software and firmware updates.

Cybersecurity: An Essential Component of Data-Driven Healthcare and Connected Devices

Healthcare organizations face a significant threat from data breaches, which can compromise sensitive patient information such as personal details and medical records. As these groups become increasingly reliant on digital healthcare technologies like electronic health records (EHRs) and telemedicine, there is a critical need for robust cybersecurity measures. Meanwhile, the shift towards telehealth and remote patient monitoring has significantly expanded the attack surface for cyber threats, and the expansion of connected devices can further increase the potential for cyberattacks. Compliance with regulations like HIPAA is essential to safeguard patient data, as non-compliance can lead to severe legal and financial repercussions.

Cybersecurity incidents can carry considerable financial and reputational costs for companies and healthcare systems. In 2023 alone, groups like HCA Healthcare (11 million impacted), HealthEC LLC (4.5 million impacted), and Beaumont/Corewell Health (1 million impacted) all experienced breaches with compromised data ranging from names to service dates and other personal information. Data breaches in healthcare are particularly costly. According to an IBM report, the average cost of a data breach in the healthcare sector in 2019 was \$6.45 million, significantly higher than the average cost of \$3.92 million across other industries.²⁷ The cost per breached record in healthcare was also notably higher—\$355 compared to \$158 for non-healthcare records. These costs encompass immediate damages, ongoing security improvements, and long-term reputational damage, which can haunt organizations for years.

Safeguarding patient data is not just a regulatory requirement but also a fundamental aspect of patient care and organizational integrity. By investing in advanced cybersecurity measures and fostering a culture of security awareness, organizations focused on human health innovation can better protect their data assets and maintain the trust of their patients and stakeholders. These incidents highlight the vulnerability of healthcare organizations to cyberattacks and the extensive impact such breaches can have on individuals and institutions alike.

Cybersecurity represents a critical shared concern among the region's stakeholders involved in data-driven healthcare and connected devices. Factors such as the loss of patient health records, rising instances of medical identity fraud, and the growing adoption of cloud-based solutions in healthcare are expected to propel the cybersecurity market in this sector. BCC Research finds that the global market for healthcare cybersecurity is \$13.8 billion in 2024, and it is expected to grow 8.1 percent CAGR from 2024-2029 and reach \$20.4 billion.²⁸

²⁷ <https://www.ibm.com/downloads/cas/RDEQK07R>

²⁸ BCC Research: Global Market for Cybersecurity, by End-User Industry, Through 2029

It should also be noted that there are several unique assets that the Pittsburgh region has in terms of tissue repositories and biobanks that are of relevance to both the data-driven healthcare and the other strategic platform to be discussed, next-generation therapeutics. These assets provide genetic and other material for generating valuable data and are essential resources for informing the development and testing of potential biomarkers, diagnostics, and therapeutics.

Biobanks: A Bridge Between Data-Driven Healthcare and Precision Medicine

Biobanks play a crucial role in advancing precision medicine and data-driven healthcare by providing researchers with extensive collections of biological samples and associated clinical data. These vast repositories of tissue, blood, and genetic samples can enable large-scale studies that can uncover biomarkers, validate potential drug targets, and develop strategies for personalized treatment. Biobanks are a unique data asset in the region:

- **The National Surgical Adjuvant Breast and Bowel Project (NSABP)**, initiated by renowned breast cancer researcher Bernie Fisher, is a clinical trials cooperative group with a 50-year history of conducting groundbreaking studies that have transformed breast cancer treatment and prevention. The NSABP has enrolled over 110,000 participants in clinical trials, establishing lumpectomy plus radiation as the standard surgical treatment for breast cancer and demonstrating the effectiveness of adjuvant therapy in improving survival rates.
- **The Pitt Men's Study (PMS)** is a confidential research study on HIV/AIDS that has since 1984 followed a cohort of approximately 3,000 men to gather crucial information on the epidemiology, virology, immunology, and pathology of HIV. As part of the MACS/WIHS Combined Cohort Study, PMS contributes to one of the world's largest HIV/AIDS-related tissue specimen banks, offering valuable insights into the impact of chronic health conditions on people living with HIV.
- **The Chuck Noll Foundation for Brain Injury Research** is dedicated to advancing research related to the diagnosis and treatment of sports-related brain injuries, with a focus on developing innovative technologies for non-invasive neural signal measurement in concussion patients. The foundation supports important brain injury research and houses one of the world's largest brain banks.
- **The Chan Soon-Shiong Institute of Molecular Medicine at Windber**, formerly known as Windber Research Institute, is a biomedical research center focused on translational research to improve healthcare and quality of life. The institute is now associated with biotech pioneer Patrick Soon-Shiong after having previously served as the U.S. Military's breast cancer tumor bank.
- **Predictive Oncology**, formerly known as Helomics, is a bioinformatics company that leverages AI and ML to improve drug discovery and development in oncology. The company boasts one of the world's largest tumor banks with over 150,000 tumor samples that are used in conjunction with their PEDAL platform to make high-confidence predictions of drug responses and optimize drug discovery processes.

Strategy 2: Support the advancement of a next-generation therapeutics and precision medicine platform.

Rationale:

New therapeutic modalities, including small volume personalized therapeutics, cell therapies, and gene therapies, represent a disruptive space for the current biopharmaceuticals industry. Building upon the region's clinical expertise, disruptive change presents new opportunities to advance a deep base of research in relevant areas of biological sciences and the forthcoming operations of BioForge and ElevateBio. Complementing these assets are a robust series of regional core competencies in automation science, chemical engineering, and advanced manufacturing, which may have high relevance to advancing the efficient, repeatable, quality-assured, and cost-effective production of next-generation therapeutics and other associated clinical products.

The next-generation therapeutics and precision medicine platform focuses on the convergence of innovation across drug discovery and development, production technologies and automation, and advanced and precision therapeutics. Important areas of emphasis within this platform include the reliability and speed of therapeutics manufacturing and the management of the tremendous amounts of data that come from individualized therapeutics. The Pittsburgh region has the potential to be a leading innovator across both elements.

Examples of sub-areas within the next-generation therapeutics and precision medicine platform include topics such as peptide therapeutics, cell therapies, gene therapies, RNA-based therapeutics, and the efficient custom formulation/dosing/production of precision medicines. It represents a wide-ranging opportunity space that can draw from a rich clinical research base for candidate innovations. It is also an area where regional capabilities in advanced manufacturing, automation, robotics, and associated regional core competencies may be brought to bear on the distinct needs to advance repeatability, high-level quality control, and efficiency in biomanufacturing processes. As noted previously in Figure 10, there is a complementary overlap with the data-driven healthcare platform, with data analytics being of high relevance to both drug discovery and the production process.

The next-generation therapeutics and precision medicine platform is intended to build upon current and forthcoming assets and core competencies to provide a complementary and supportive ecosystem for innovation. While the Pittsburgh region does not have a large legacy industry in the small molecule (traditional pharma) or large molecule (biotech) sectors—except for Viatriis, formerly Mylan, in generic pharmaceuticals production—the industry is evolving in terms of new therapeutics and production technologies that are not produced in the large batches or continuous streams of traditional pharma and biotech. Rather, these new therapeutics represent customizations or amplifications of individual patient cells, or otherwise specifically tailored medicines compounded to meet new precision medicine needs

that enable the promise of personalized medicine for individual patients. The ecosystem to support the development, piloting, testing, and production of these next-generation therapeutics is presently being built with a \$255 million investment in BioForge as its centerpiece. Focus group discussions and other intelligence provided during the strategic planning process identified other elements of the ecosystem that will need to be built or addressed to complement BioForge and help realize a vision of Pittsburgh becoming a leader in the manufacturing of next-generation therapeutics. It is these elements, both additions to the ecosystem as well as enhanced connectivity between existing assets, which are the focus of this strategy.

Research Strengths in Next-Generation Therapeutics and Precision Medicine

The potential for the development of a significant cluster of companies in next-generation therapeutics is contingent, in part, on the flow of relevant medical discoveries and innovations from the region’s extensive research enterprise. Working in the Pittsburgh region’s favor is that areas of medicine seeing the most progress in cell and gene therapies are also areas of distinct core competencies in the region (Table 4).

Table 4: Leading Areas of Cell and Gene Therapy Development

Field	Trends in this Sector	Pittsburgh’s Core Competency Position ²⁹
Oncology	Cancer is a key area for cell and gene therapy development. CAR-T cell therapies represent 52 percent of genetically modified cell therapies in the pipeline. In February 2024, lovance’s Amtagvi became the first FDA-approved cell therapy for a solid tumor (advanced melanoma).	<ul style="list-style-type: none"> • Oncology (5,826 publication records, LQ: 1.75) • Themes from Topic Modeling Analysis: <ul style="list-style-type: none"> • Immunotherapy in solid tumors; pediatric tumors • Cancer cell growth; cell therapy and antigen receptor management • Adjuvant therapy, chemotherapy, and drug outcomes • Radiation therapy and stereotactic radiosurgery • Cancer types: breast, lung, lymphoma, leukemia, colorectal, carcinoma, prostate, ovarian and endometrial, melanoma, pancreatic. • Notable companies include Precision Oncology, BlueSphere Bio, KaliVir Immunotherapeutics, Biohaven (formerly Knopp Biosciences), and Cernostics.
Rare Genetic Diseases	A highly active space, with several gene therapies for rare disorders are advancing: <ul style="list-style-type: none"> • Orchard Therapeutics’ Lenmeldy was approved in March 2024 as the first gene therapy for metachromatic leukodystrophy. • Rocket Pharmaceuticals has a gene therapy for leukocyte adhesion deficiency-1 under FDA review. 	<ul style="list-style-type: none"> • Genetics/Hereditry (1,873 publication records, LQ=1.20) • Themes from topic modeling analysis: <ul style="list-style-type: none"> • Blood disorders • Muscular dystrophy • Pediatric Lyme disease • PKU • Notable companies include Krystal Biotech, Peptilogics, Lygenesis, and Imagine Pharma.

29 TEconomy’s analysis of Clarivate Analytics Web of Science and Pitchbook Data

Field	Trends in this Sector	Pittsburgh's Core Competency Position ²⁹
Neurology	Neurological conditions are an emerging focus, with gene therapies for conditions like Alzheimer's disease and Parkinson's disease in development.	<ul style="list-style-type: none"> • Clinical Neurology (4,855 publication records, LQ=1.81) • Neuroimaging (531 publication records, LQ=1.75) • Neurosciences (4,331 publication records, LQ=1.29) • Themes from topic modeling analysis: <ul style="list-style-type: none"> • Down Syndrome clinical care and neurocognitive regression • Mental health, PTSD, depression, trauma, anxiety, psychosis, schizophrenia, bipolar, stress, suicidal behavior • Parkinson's disease and Alzheimer's disease • Visual cortex studies • Neural electrode technology • Brain-computer interfaces • Imaging and inertial sensors • Notable companies include Cognition Therapeutics.
Ophthalmology	Eye disorders are well-suited for gene therapy approaches, and gene therapies for inherited retinal diseases continue to advance through clinical trials	<ul style="list-style-type: none"> • Ophthalmology (1,030 publication records, LQ=1.56) • Themes from topic modeling analysis: <ul style="list-style-type: none"> • Corneal outcomes from treatment of ocular disorders • Corneal transplants and tissue generation • Age-related macular degeneration treatment • Keratitis and other infections • Notable companies include Avista Therapeutics.
Hematological Disorders	<p>Hemophilia and blood disorders continue to be a major focus:</p> <ul style="list-style-type: none"> • Pfizer's Beqvez gene therapy for hemophilia B is awaiting FDA approval in April 2024. • Gene therapies for sickle cell disease and beta thalassemia, like Vertex/CRISPR's Casgevy, received approval in late 2023/early 2024. 	<ul style="list-style-type: none"> • Hematology (1,587 publication records, LQ=1.69) • Themes from topic modeling analysis: <ul style="list-style-type: none"> • Rare blood disorders including hemophilia, Von Willebrand disease, and sickle cell disease.
Regenerative Medicine	Regenerative medicine harnesses cell and gene therapy technologies to help restore normal functions and potentially cure previously untreatable conditions.	<ul style="list-style-type: none"> • Transplantation (942 publications, LQ=2.4). • Themes from topic modeling analysis: <ul style="list-style-type: none"> • Stem cell-based regeneration of bone, tissue, and cartilage • Hepatocyte-driven liver regeneration • Notable companies include Cook Myosite, Krystal Biotech, Lygenesis, and ECM Therapeutics.

The pipeline of cell and gene therapies is expanding rapidly across multiple therapeutic areas.³⁰ In Q1 2024, there were over 4,000 gene, cell, and RNA therapies in development globally.³¹ Of these, gene therapies comprised 52 percent of the pipeline, followed by RNA therapies (26 percent) and non-genetically modified cell therapies (22 percent). The field is seeing strong growth across all clinical development stages, with an 11 percent increase in Phase I programs from Q4 2023 to Q1 2024.³² This broad expansion suggests cell and gene therapies will likely transform treatment paradigms for numerous diseases in the coming years.

BioForge: A Transformative Investment

The region's potential to capture market share in this exciting therapeutics space has been greatly advanced by the RK Mellon Foundation's philanthropic gift of \$100 million to help establish BioForge.

BioForge is a state-of-the-art biomanufacturing facility being developed by Pitt in the Hazelwood Green neighborhood. The 185,000-square-foot facility is designed to accelerate innovations and breakthroughs in the manufacturing of precision biologic medicines to speed their delivery, use, and impact. Anchored by ElevateBio, a leading biotech company, BioForge will house advanced manufacturing capabilities, wet labs, and additional spaces to foster innovation in precision medicine. Without this transformative investment, the region would have been significantly disadvantaged in advancing next-generation therapeutics as it would have lacked not only the lab space that BioForge provides but also the services that ElevateBio provides as a world-class contract development and manufacturing organization (CDMO). Together, BioForge and ElevateBio address the region's most serious ecosystem gaps.

ElevateBio stands out as a significant partner for BioForge due to its extensive expertise in cell and gene therapy manufacturing and its comprehensive end-to-end solution approach. The company brings advanced technologies, including gene editing and cell engineering, along with a proven track record of successfully manufacturing complex therapies. ElevateBio's industry partnerships and network can help attract additional companies and investments to the region, while its commitment to innovation aligns well with the region's strengths in robotics and AI. As BioForge leverages ElevateBio's industry expertise and advanced manufacturing capabilities, the region has gained a proven leader in accelerating the development of cutting-edge therapies. The BioForge investment will help drive Pittsburgh's potential to become a leading center for next-generation biomanufacturing innovation and for the commercialization of novel next-generation therapeutics.

30 <https://www.advisory.com/topics/clinical-innovation/2024/06/cell-gene-therapy-pipeline>

31 <https://www.asgct.org/global/documents/asgct-citeline-q1-2024-report.aspx>

32 Ibid.

Additional Assets to Leverage

Complementing BioForge and advancing the potential for the region to become a leader in next-generation therapeutics, are a series of regional assets that may be relevant to and pivoted towards next-generation therapeutics production. The production pathways to manufacture small molecule and large-molecule biotech drugs in volume are well-established (although there is still room for improvements in processes for continuous manufacturing and in the use of disposable production systems). When it comes to cell therapies, gene therapies, and other new categories of advanced and precision medicines, the technologies, processes, and control systems for manufacturing and distribution are still “a work in progress.” While there are FDA approved processes being deployed (and there are approved next-generation clinical therapeutics on the market, as noted in Table 4), there is a large-scale opportunity to improve and automate production processes to ensure repeatability and reduce production costs. It is still unknown whether the industry will evolve to be similar to traditional pharmaceuticals in terms of significant investment in major centralized manufacturing plants, or if the new therapeutics will benefit from small or modular production operations distributed widely throughout the nation or even be produced at actual sites of clinical care in small scale operations.

As noted earlier in this report, innovation spaces that involve or favor convergence (multiple disciplines being brought together to address an opportunity) are a relatively new and dynamic phenomenon with great economic promise. The facilitated convergence of biology, chemistry, computer and data sciences, automation and robotics, materials science, operations research, and other fields are required to address the manufacturing challenges and opportunities in next-generation therapeutics. These are areas where the Pittsburgh region has notable and distinctive core competencies and, in some cases, world-class infrastructure and research centers. These assets have not yet been integrated into an ecosystem for next-generation therapeutics process development. However, BioForge has started discussions and there is a compelling case to be made that the Pittsburgh region can become a leading center for advancing innovations, technologies, and industries focused on this opportunity space. Some of the signature core competencies that may be engaged, include:

- Robotics and automation sciences, most notably within CMU, but also more broadly distributed within the academic and technology industry base in the region.
 - CMU's Robotics Institute, and the associated National Robotics Engineering Center, work closely with academic, government, and industry clients to develop and mature applied robotics and automation technologies.
 - The Advanced Robotics for Manufacturing (ARM) Institute in Hazelwood, which also shares space with CMU's Manufacturing Futures Institute, is a key hub for automation advancement in manufacturing.
- Chemical engineering is a long-standing academic strength.
- Top ranked programs in AI, machine learning, and machine vision,³³ which provide a rich base of expertise to draw upon on both the discovery side of next-generation therapeutics and in the advancement of manufacturing and processing technologies.

33 TEconomy's analysis of CSRankings, a metrics-based ranking of top computer science institutions around the world. See: <https://csranks.org/>

- Number one ranked program in Computational Biology (as measured by CSRankings), providing world class capabilities in informatics, including both bioinformatics (of relevance to this platform) and health informatics (of relevance to the data-driven healthcare platform). The intersection of CMU's expertise in computational biology in concert with the expertise of Pitt, UPMC, AHN and others in this subject area and its application to therapeutics innovation is a signature core competency for the region.

On the drug and therapeutics discovery side of the equation, in addition to multiple areas of relevant and potentially relevant clinical excellence, the region's life sciences ecosystem is also supported by a range of translational research and commercialization initiatives that facilitate the advancement of biomedical innovation. Central to this ecosystem is Pitt, which hosts several key institutes and initiatives focused on translating scientific discoveries into practical applications. One of the signature initiatives is the NIH-funded Clinical and Translational Science Institute (CTSI) that acts as a hub for translational research, providing pilot funding and resources to help researchers develop biomedical innovations. In collaboration with UPMC, CTSI offers access to clinical resources, specialized core labs, and support for biospecimen collection, data access, and advanced analysis.

The McGowan Institute for Regenerative Medicine is a long-standing prominent center for tissue engineering and cellular therapies. It involves over 200 clinicians, scientists, and engineers, and has established more than 50 partnerships with industry resulting in over \$20 million in sponsored research and nearly 160 licenses granted. The institute also has a dedicated business relations office to facilitate collaborations and has seen the formation of 25 spinout companies by its affiliated faculty.

These, and other initiatives (see sidebar) are indicative of a growing commitment to bridge the gap between research and practical application, foster a supportive environment for life sciences innovation, and advance entrepreneurship.

Additional Examples of Centers at the University of Pittsburgh with Relevance to the Platform:

- Center for Clinical Pharmaceutical Sciences
- Center for Computational Biology and Bioinformatics
- Center for Pharmacogenetics
- Center for Pharmaceutical Policy and Prescribing
- Center for Vaccine Research
- Computational Chemical Genomics Screening Center, and
- Fox Center for Vision Restoration.

It should also be noted that AHN is engaged in work directly relevant to this platform. The AHN Cellular Therapeutics Institute conducts research aimed at developing novel, safe, and effective medical breakthroughs, particularly in the realm of personalized cellular therapies. A significant focus of the institute is to reduce the prevalence of diabetes through innovative research and treatments, translating scientific discoveries into clinical applications. AHN's work in cell and gene therapies is, however, far broader. AHN has established itself as a leader in cell therapy and gene therapy research, with a diverse portfolio of innovative approaches aimed at treating various diseases. The institution's research efforts span several key areas, demonstrating a commitment to advancing cutting-edge treatments. In the field of cancer treatment, AHN is one of the few centers nationwide offering CAR T-cell therapy, particularly for aggressive blood cancers such as leukemia and lymphoma. The network's on-site manufacturing

capabilities for CAR T-cells, using advanced technology (including the CliniMACS Prodigy platform), allow for reduced production time and fresh cell infusion. Complementing this, AHN is conducting clinical trials using Tumor Infiltrating Lymphocytes (TILs) for various cancer types, with plans for expansion.

AHN's Cell Transplantation Program is working on stem cell transplants for blood cancers and other disorders. The health system's oncologists are also at the forefront of immunotherapy research, developing treatments to enhance the immune system's ability to target cancer cells more effectively. In autoimmune diseases, AHN researchers are making significant strides in developing tolerogenic dendritic cell therapy, particularly for type 1 and type 2 diabetes. Islet cell research is another area of focus at AHN, with teams working on isolating and processing pancreatic islets for both clinical and research purposes.

Industry Strengths in Next-Generation Therapeutics and Precision Medicine

While BioForge and the presence of ElevateBio will provide a transformational expansion of regional capabilities in cell therapy, gene therapy, and next-generation therapeutics, even in their absence multiple companies have formed in and around this dynamic space in the Pittsburgh region (Figure 17). This emerging base of companies in cell therapies, gene therapies, and niche biopharmaceuticals (i.e., orphan diseases) include, for example:

- Krystal Biotech (232 employees; 8 Regional Patents; \$5.8 billion market capitalization as of August 2024)
- Knopp Biosciences (now part of BioHaven) (16+ local employees; 18 Regional Patents; \$3.9 billion in market capitalization as of August 2024)
- Predictive Oncology (140 employees; \$247M in VC Raised)
- BlueSphere Bio (49 employees; \$56M in VC Raised)
- Peptilogics (25 employees; 8 Regional Patents; \$42M in VC Raised).
- Cook Myosite (200 employees).

Viatrix, a major pharmaceutical company operating in Canonsburg (800 Employees; 7 Regional Patents), is best known for its manufacturing of generic drugs; however, its capabilities extend further with patent generation in informatics. In November 2020, Viatrix was formed through the combination of Mylan and Upjohn (which was created by Pfizer's Established Medicines division in 2018).

Also notable is the presence of Thermo Fisher Scientific, a global company with a high degree of engagement in the cell and gene therapy sector. At the present time, however, the company's relevant activities are centered in California. Pittsburgh is home to the Fisher Scientific brand operations of the company, which is a major operation in the region with over 1,500 employees, and representatives of the company are members of the PLSA and have been engaged in the strategy development process. While cell and gene therapy business lines of the company are not in Pittsburgh, the local presence of Fisher Scientific provides valuable potential connectivity into the comprehensive end-to-end solutions provided by the company in the space—from initial discovery to commercial manufacturing. In cell therapy manufacturing, Thermo Fisher provides advanced tools and technologies, including closed manufacturing systems and single-use technologies. For gene therapy applications, the company offers solutions for plasmid construction, vector production, and purification, addressing key challenges in this area. Thermo Fisher's capabilities extend to cell isolation, engineering, and expansion, which are used in developing advanced therapies such as CAR-T cells. They also provide essential analytical and characterization services, including lot release testing, product

characterization, and quality control, ensuring the safety and efficacy of cell and gene therapy products. The company also develops innovative technologies, such as the CTS Rotea Counterflow Centrifugation System and the CTS Xenon Electroporation System, to advance cell therapy applications.

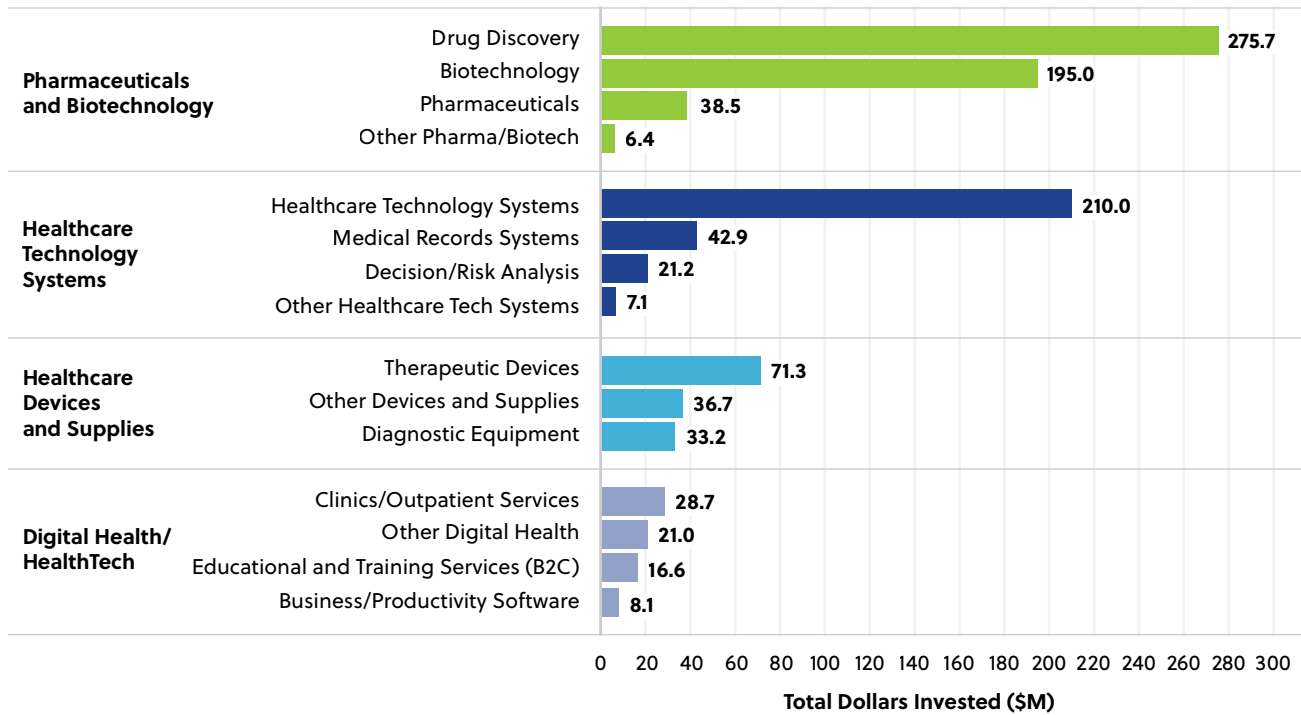
Figure 17: Examples of Companies Engaged in the Personalized Medicine and Next-generation Therapeutics Arena in the Pittsburgh Region.



Source: TEconomy Partners, LLC

Analysis of VC data finds support for the next-generation therapeutics platform as drug discovery and biotechnology writ large are two of the leading areas for life sciences investment in the Pittsburgh region (Figure 18). Whether or not the companies receiving these funds are in cell and gene therapy, or other product space, the results show that regional therapeutics ventures can secure VC funding.

Figure 18: Venture Capital Invested by Subsector (2018-2023)



Source: TEconomy’s analysis of Pitchbook Data

Market Size and Potential

This platform is aligned with significant global markets that are growing extremely quickly. BCC Research finds that the global market for precision medicine is expected to reach \$100.5 billion by 2028, growing at 13 percent CAGR from the 2023-2028 forecast period.³⁴ While the cell and gene therapies market is expected to be smaller, reaching \$23.3 billion in 2028, this market is growing extremely quickly—forecasted at 26 percent CAGR from 2023-2028.³⁵

It is recommended that the Pittsburgh region pursue three strategies to support the advancement of a next-generation therapeutics and precision medicine platform:

- Action 2.1: Leverage BioForge to establish a regional strength in enhancing the speed and quality of advanced therapeutics production.
- Action 2.2: Encourage growth in clinical trials to accelerate new therapeutic development.
- Action 2.3: Further develop the precision medicine ecosystem and supply chain with targeted business attraction and development efforts.

34 BCC Research: Precision Medicine
 35 BCC Research: Cell and Gene Therapies

Action 2.1: Leverage BioForge to establish a regional strength in enhancing the speed and quality of advanced therapeutics production.

BioForge's research activities combined with ElevateBio's CDMO capabilities are likely to form a hub of a burgeoning cell and gene therapy sector, helping to build upon the small base of companies in the space currently. There is an opportunity for BioForge and ElevateBio to be involved in helping to engage the many assets of the region relevant, or potentially relevant, to next-generation therapeutics production.

Expertise in robotics, autonomy, automation science, AI and advanced data analytics, IoT, and cybersecurity can lead to developing solutions for the key challenges in cell therapy and gene therapy manufacturing. As noted previously, these represent a very different paradigm in terms of manufacturing for the therapeutics industry and there are multiple areas of opportunity for R&D, innovation, and business development to occur around needs in:

- Increasing the speed of production
- Assuring quality control and repeatability across all stages of production
- Lowering the cost of production of precision and personalized medicines
- Managing the tremendous amount of data that comes with individualized production runs.

Potential Action Components:

- Leveraging BioForge as a foundation to support speed and quality in advanced therapeutics by emphasizing various approaches, and engaging multi-disciplinary/multi-institutional teams, in key technology areas (e.g., process optimization, automation/robotics/AI, scale-up technologies, and supply chain optimization).
- Leverage the region's data management and analytics strengths to develop solutions for continuous monitoring, improvements to manufacturing processes, and quality control.
- Developing a collaborative research program with funding incentives where scientists and engineers may work on speed/quality advancement projects (i.e., cross-disciplinary research projects with existing institutions in the region and/or joint projects with industry).

Action 2.2: Encourage growth in clinical trials to accelerate new therapeutic development.

Advancing novel therapeutics from the lab towards commercialization requires the performance of clinical trials. Indeed, part of the mission of BioForge and ElevateBio will be the production of experimental therapeutics for use in trials. One of the issues identified is that the Pittsburgh region, overall, is not viewed as a leading environment for the performance of trials. Issues raised included conservative IRBs and a perception that organizations are somewhat slow in terms of establishing agreements and/or executing any required amendments to agreements. While the region has a significant number of clinical trials, feedback from industry and leading clinicians suggests there is potential for far more if more responsive processes and infrastructure can be developed.

Building a significant presence in the next-generation therapeutics space (which is already a fast moving and dynamic entrepreneurial space) will be constrained if the execution of business-to-university agreements are uncompetitively slow and if institutions continue to be viewed as presenting a challenging environment for conducting clinical trials. It is certainly no easy task to change the culture and processes of very large and established institutions, but it needs to be a priority, or the ecosystem will be hampered by a significant gap in capabilities. The region's institutions note that they recognize this is an area where improvement is possible, and a variety of initiatives are underway to address identified challenges.

Pursuing Leadership in Clinical Trials

An analysis of more than 20,000 clinical trials across the identified benchmarks finds that the Pittsburgh region is engaged in trials activity, but the region is moderately lagging as it relates to both industry-led and, particularly, PI-led clinical trials.³⁶

In industry-led clinical trials, the Pittsburgh region is moderately trailing most benchmarks. Approximately 54 percent of Pittsburgh's clinical trials were identified as industry-led, versus Research Triangle (55 percent of total trials in region), Seattle (58 percent of total trials), and Nashville (74 percent of total trials).

An analysis of PI-led clinical trials (those with a lead sponsor, PI, study chair, or study director in the region) finds that Pittsburgh is further behind most benchmarks. An estimated 9 percent of total regional trials analyzed in Pittsburgh were "PI-led trials with a lead sponsor, PI, study chair, and/or study director in the region," well-behind Boston (nearly 30 percent of total trials) and other regions like Raleigh-Durham (19 percent of total trials) and Seattle (14 percent of total trials).

36 TEconomy's analysis of ClinicalTrials.gov data.



An option to consider, given the platform focus opportunities, may be to pursue clinical trials improvement and process streamlining for clinical areas that are likely to be relevant to cell and gene therapies and other next-generation therapeutic areas (rather than trying to revise the entire enterprise). Setting up specialized clinical trial units equipped just for cell and gene therapy trials may be a potential solution.

Based on the input received, several potential action components may be considered.

Potential Action Components:

- Understand/support current activities by universities and health systems to enhance performance in this space.
- Boost connectivity between industry and practitioners for advice, feedback, testing, and trials.
- Build on Action 1.2 (“voice of customer” platforms) and develop a structured system to connect regional life sciences companies with clinical expertise from major healthcare providers like UPMC and AHN to significantly boost innovation across the region's burgeoning life sciences sector.

Action 2.3: Further develop the precision medicine ecosystem and supply chain with targeted business attraction and development efforts.

BioForge, and the engaged CDMO and other services of ElevateBio, represent the core of building out a complete ecosystem for next-generation therapeutics development, production, and testing in the region—but BioForge is not a complete ecosystem in and of itself. Focus groups, interviews, and benchmarking review suggest that multiple contract services and supply chain elements would be valuable to develop or attract to the region in order to build a strong ecosystem for cell and gene therapies and other next-generation therapeutics. Developing or attracting these services and supply chain elements would create a more comprehensive ecosystem, supporting not only BioForge and ElevateBio but also attracting other companies in the cell and gene therapy space to the Pittsburgh region. Examples of potential business areas to attract may include those shown in Table 5.

Table 5: Examples of Contact Services and Supply Chain Elements Required for a Holistic Next-generation Therapeutics Business Ecosystem to Develop in the Pittsburgh Region.

Business or Service Area	Key Elements
Specialized Contract Research Organizations (CROs)	<ul style="list-style-type: none"> • Focus on preclinical and clinical trial services for cell and gene therapies. • Expertise in regulatory affairs specific to advanced therapies.
Cell Line Development Services	<ul style="list-style-type: none"> • Companies specializing in developing and characterizing cell lines for therapeutic use.
Analytical Testing Services	<ul style="list-style-type: none"> • Specialized in characterizing cell and gene therapy products. • Capabilities for potency assays, genomic analysis, and product purity testing.
Quality Control and Release Testing Services	<ul style="list-style-type: none"> • Providers of rapid microbial testing and other specialized QC services for cell therapies.
Raw Material Suppliers	<ul style="list-style-type: none"> • Providers of high-quality, GMP-grade materials for cell culture and gene editing. • Suppliers of viral vectors and plasmids. • Suppliers of specialized packaging materials for clinical grade products, including products that enable low temperatures to be maintained.
Automation and Software Providers	<ul style="list-style-type: none"> • Developers of software for manufacturing execution systems (MES) specific to cell and gene therapies. • Providers of automation solutions for cell processing and quality control.
Single-Use Bioreactor and Bioprocessing Equipment Manufacturers	<ul style="list-style-type: none"> • Companies producing specialized equipment for cell therapy manufacturing.
Cold Chain and Logistics Providers	<ul style="list-style-type: none"> • Expertise in handling and transporting temperature-sensitive cell and gene therapy products. • Cryogenic and other cold chain storage facilities.



Business or Service Area	Key Elements
Specialized Equipment Maintenance and Calibration Services	<ul style="list-style-type: none"> • Companies capable of servicing and calibrating the specialized equipment used in cell and gene therapy manufacturing.
Biomedical Informatics and Data Management Services	<ul style="list-style-type: none"> • Providers of specialized software and data management solutions for tracking cell therapies from donor to patient.
Cleanroom Design and Construction Services	<ul style="list-style-type: none"> • Companies experienced in building GMP-compliant facilities for cell and gene therapy manufacturing.
Regulatory Consulting Firms	<ul style="list-style-type: none"> • Experts in navigating the complex regulatory landscape for advanced therapies.
Specialized Legal and Intellectual Property Services	<ul style="list-style-type: none"> • Firms with expertise in biotech patents and licensing for cell and gene therapies.
Specialized Workforce Training Programs	<ul style="list-style-type: none"> • Institutions offering training in GMP manufacturing, quality control, and regulatory compliance for cell and gene therapies.

In pursuit of a comprehensive ecosystem for next-generation therapeutics, several action components may be considered:

Potential Action Components:

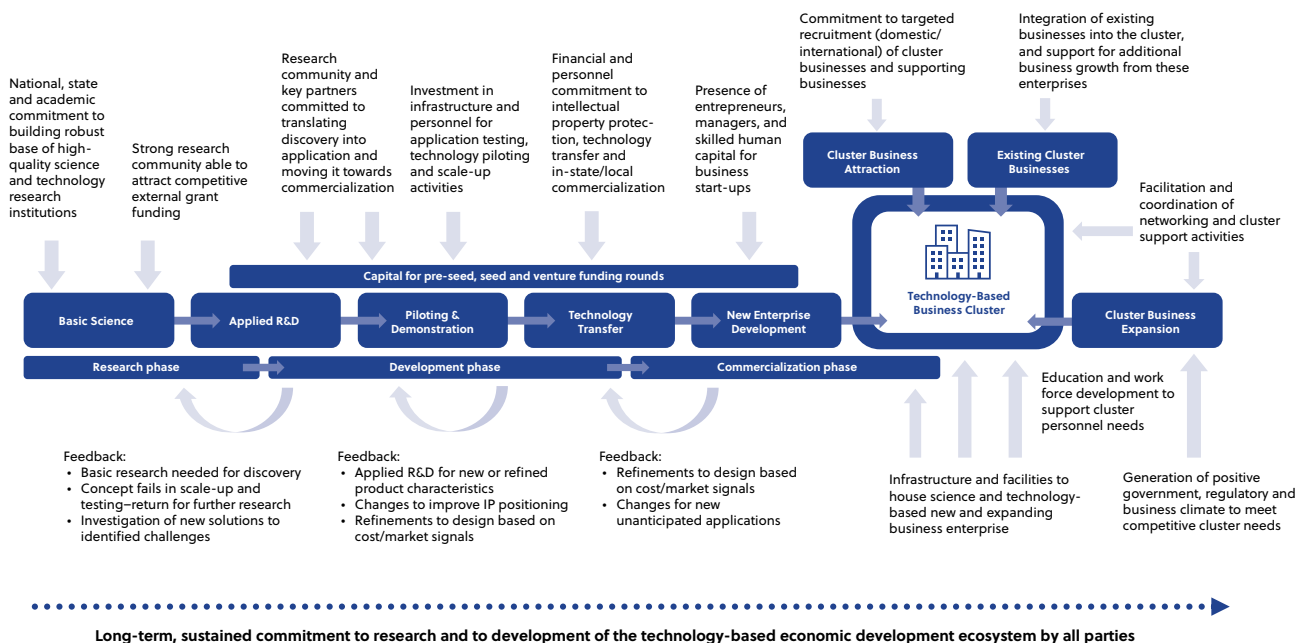
- BioForge, ElevateBio, and regional companies engaged in the next-generation therapeutics space should be convened to evaluate the list provided in Table 5 and identify if these elements are already provided in the region, prioritize those elements that need to be addressed, and consider other areas not listed that may be required.
- Identify potential strategic sites conducive to interactions with BioForge to help support growing companies. This is likely to comprise site development at Hazlewood Green and nearby developments including the Pittsburgh Technology Center and South Side Works.
- Investigate incentives that may be best suited for supporting and accelerating successful recruitment to the region of preferred supply chain companies and service providers.
- Identify existing regional businesses that can, or may have the potential to, fulfill key elements of the ecosystem. Connect BioForge and these businesses to discuss opportunities for business development and collaborations.
- Consider the creation of a regional preferential access program for areas with academic medical centers and innovative companies that may benefit from having access to the assets in Pittsburgh. Negotiating such access, on preferential terms, may generate increased projects and deal flow into the Pittsburgh ecosystem and also have the additional benefit of reducing the incentive for these other hubs to develop competing assets. Logical locations to approach would include Cleveland, Akron, Morgantown, and Columbus, each of which have significant academic medical centers.
- Connect with similar cluster development initiatives regionally (i.e., AI/robotics, advanced manufacturing, energy) that are already partnering and can potentially benefit the life sciences.
- Develop a shared repository of information on manufacturing best practices and cost reduction strategies and connect with similar initiatives worldwide to share best practices and build the region's profile as a thought leader.
- Identify opportunities to leverage investments at the restructured Greater Pittsburgh International Airport suited to the needs of next-generation therapeutics logistics and cold-chain warehousing.
- Explore innovation around packaging and materials for next-generation therapeutics, engaging regional core competencies in materials science and engineering.

Strategy 3: Reinforce the life sciences ecosystem to enhance the “stickiness” for innovative companies.

Rationale:

Innovation-led economic development is complex, requiring a focus on every element of the value chain, from the research phase through commercialization and into the development of a thriving technology-based industry cluster (Figure 19). If components of this integrated ecosystem are weak or missing, sustainable economic growth is unlikely to develop. Meanwhile, regions that have strategically focused resources on creating a holistic, well-functioning, economic development ecosystem are prospering.

Figure 19: The Complexities of Innovation-Led Economic Development

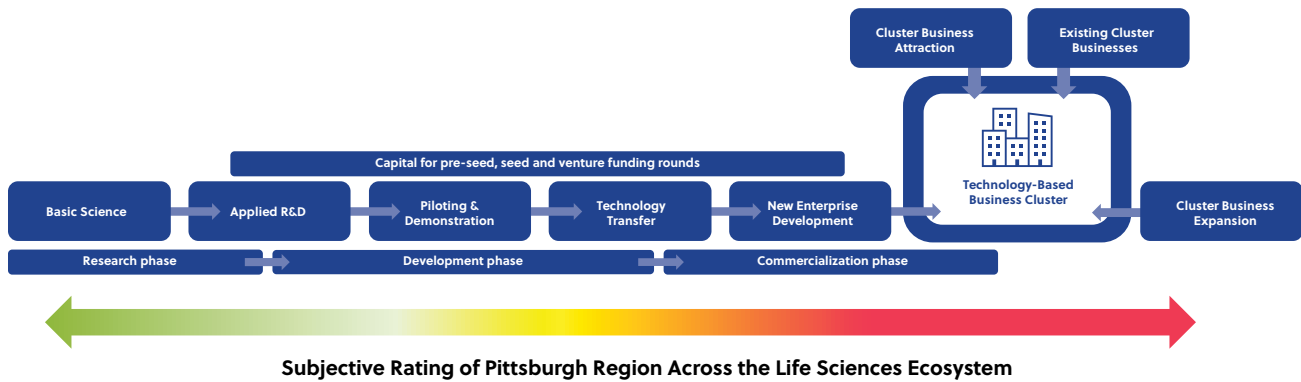


Source: TEconomy Partners, LLC

While the Pittsburgh region has made great strides in supporting life sciences entrepreneurship and innovation, there is still a sense that the region has not yet reached its full potential due to a range of disconnects within the broader ecosystem. TEconomy’s situational assessment of the region’s ecosystem finds that performance begins to lag at the later stages of the value chain (Figure 19). Life sciences research and development is a hallmark of the regional economy, and the region’s research universities tend to perform relatively well in technology transfer and commercialization when looking at overall

volume of activity. However, the region is substantially underperforming in venture development and capital attraction, and has much lower levels of industry performance, growth, and productivity. While the Pittsburgh region has been successful in the creation of new ideas, there has been comparatively less success with the creation of a sustained life sciences industry.

Figure 20: Perceptions of Pittsburgh Region’s Life Sciences Ecosystem³⁷



Source: TEconomy Partners, LLC

Accordingly, the region should focus on the gaps in the ecosystem that are the biggest barriers to the growth and scalability of its innovative ventures. Based on interviews and focus groups, four areas stand out as impeding new business development and growth:

- A lack of experienced management talent that is capable of scaling life sciences companies
- A lack of incentives for faculty to pursue translational research relevant to industry
- A need for more risk capital to fund new ventures, and
- A need to ensure that the region’s talent is connected to local industry.

As a result, the four actions included under Strategy 3 correspond directly to these challenges:

- Action 3.1: Support the next generation of life sciences companies by attracting and cultivating management talent, with an emphasis on targeted platforms.
- Action 3.2: Encourage a commercialization and entrepreneurial mindset at research-intensive universities.
- Action 3.3: Attract new forms of risk capital to the region.
- Action 3.4: Translate and connect industry needs to educational providers and workforce partners across the educational continuum.

³⁷ TEconomy’s subjective rating is for illustration purposes. In general, it was noted by most stakeholders that primary challenges in the ecosystem are in the later stages of the business development continuum.

Action 3.1: Support the next generation of life sciences companies by attracting and cultivating management talent, with an emphasis on targeted platforms.

The Pittsburgh region is home to unquestionable scientific talent, but this has not always translated to entrepreneurial success stories. Many interviews with stakeholders have expressed frustration that excellent ideas do not become successful regional businesses not because of the underlying science or technology, but instead because of poor product-market fit. This is because a key ingredient for early-stage growth in life sciences companies is having experienced management talent that is capable of starting, running, and scaling these types of business, and matching the product/technology to market demand. C-Level leaders with a history of success can create ripple effects across the life sciences ecosystem through their value-add and expertise.

Experienced management talent helps address many of the fundamental challenges related to growing and scaling successful life sciences companies. Having better management talent can help companies directly secure investment, and more experienced management talent can play a valuable role for emerging ventures by helping them to develop fundamental business strategies and a clear roadmap for progress. Seasoned management talent supports the planning of funding strategies and identifying sources of capital, crucial for securing the financial resources needed to advance life sciences businesses. Importantly, management talent can also facilitate connections with essential business partners, including corporate collaborators and both angel and follow-on investors. Through their experiences, management talent is also able to assist with technology transfer, licensing, and initial contracts, helping scientific experts navigate these complex processes. Subject-matter expertise in specialized areas such as regulatory affairs, marketing, and sales planning can prove to be invaluable for emerging ventures.

There are many potential benefits to attracting and cultivating management talent. For companies and faculty entrepreneurs, it can help eliminate the time, challenge, and expense associated with recruiting executive talent, allowing scientists to focus on other critical aspects of the business. A focused program around management talent will make businesses more attractive to potential investors. The presence of this talent also integrates emerging businesses into personal networks, and national and regional support networks, providing valuable connections and resources.

Potential Action Components:

- **Recruit a supportive community of entrepreneur peers/alumni to participate in a network.** Across the nation, and world, are a wide diaspora of people who are from the Pittsburgh region or went to a regional school. There is an opportunity to more robustly engage with individuals by creating networks of entrepreneurs, subject matter experts, alumni of regional colleges/universities, and interested ex-pats who can offer support and share their experiences. This network can help to foster collaboration and provide a platform for knowledge sharing across the entire innovation ecosystem.
- **Solicit top executive talent from across the nation who have experience with scaling innovative concepts by providing competitively funded fellowships to advance startup ideas in the Pittsburgh region.**
- **Develop a vetted referral network that is specifically focused on connecting companies in the region to a network of service providers and CEO candidates who can assist in company development.** The goal of such a network would be to facilitate company development and ensure access to a pool of qualified, vetted, and experienced talent who can contribute immediately to business growth and success.

What Others Do: Attracting and Cultivating Management Talent

In North Carolina, the BATON Referral Network represents a significant program that has proven valuable to growing and scaling life sciences companies. As one of NCBIotech's entrepreneurial programs that relies heavily on referrals to other resources, this direct offering connects companies in the NCBIotech programs to a network of service providers and CEO candidates who can assist in company development.³⁸ As a trusted resource serving the state's life sciences industry, there is great value in the pre-qualification and vetting of service providers and CEO candidates that represent a considerable array of business and technical expertise. Service providers pledge to contribute services or provide preferential pricing for referrals coming through the BATON network database. There is no cost to qualified service providers to participate in the BATON program.

38 See <https://www.ncbiotech.org/resources/baton-services>.

Action 3.2: Encourage a commercialization and entrepreneurial mindset at research-intensive universities.

Positive changes are occurring throughout the region's university structures to encourage a commercialization and entrepreneurial mindset—it will be important to continue to monitor and amplify these developments. Scientists at research universities and academic medical centers in the region are engaging in translational research and some are pursuing entrepreneurship or research projects relevant to industry, but there is a need to continue to attract more faculty with this focus and mindset.

Supporting a commercialization and entrepreneurial mindset at universities can help to cultivate an innovative academic environment where faculty are focused on practical applications for their research, not just fundamental science. To support university-industry connections requires more than universities simply conducting research for firms. Strong partnerships should address opportunities for collaborations and value-added services across the translational research paradigm from discovery to pre-clinical development to clinical testing. It is also important to create vibrant networking around shared areas of innovation, whether in regenerative medicine, digital health, immunotherapies, or personalized medicine, that offer major life sciences companies access to clinical and basic research thought-leaders, innovative emerging companies advancing cutting-edge technologies, and the broad and multi-disciplinary capabilities of university research labs.

Potential Action Components:

- **Continue to coordinate the region's advancement in technology transfer and commercialization.** Foster collaboration among the dedicated offices or centers for technology transfer and industry collaboration and identify areas of shared resources such as legal support, marketing, and business development. This could potentially help faculty across institutions more clearly navigate the commercialization process.
- **Continue to encourage pursuit of trial leadership, entrepreneurship, industry-engagement as part of tenure consideration or other university incentives.** The region's research institutions should continue to include innovation activities in their tenure considerations. There are also opportunities for the universities to incentivize innovative activities through other means, such as offering leaves of absence or sabbaticals to pursue industry facing projects.
- **Elevate the profile of regional "star" scientists.** The region is home to many eminent faculty who are already actively working in this space. The region could implement new recognition programs that highlight successful faculty entrepreneurs and research leaders and integrate these achievements into broader regional storytelling efforts (Action 4.1). This type of recognition could help motivate faculty to pursue similar achievements. The region can also continue to focus on recruiting faculty with an entrepreneurial- and translational research-focused mindset.
- **Offer training and development programs.** Provide researchers with the necessary skills and knowledge to engage effectively with industry partners via workshops and training sessions on topics such as entrepreneurship, IP management, and industry collaboration. This training can also help to introduce people to entrepreneurship early in their innovation process.

Action 3.3: Attract new forms of risk capital to the region.

Regions with thriving life sciences sectors share a common characteristic: they are home to a risk capital community that is both oriented toward early-stage financing and committed to investing in locally rooted companies. As noted in Figure 20, entrepreneurs require access to capital at each stage of their development, from early-stage, proof-of-concept and prototype development to Series A and B venture financing. Regions wishing to grow entrepreneurial companies around the life sciences have used a variety of mechanisms to encourage investment in venture capital and to address market gaps, particularly at the commercialization and pre-seed stages.

Emerging trends in capital markets point to the importance of having locally rooted funds focused on the growth of innovative firms. These indigenous funds help in identifying promising discoveries and technology advances, providing the initial funding to validate these opportunities, supporting the formation of new ventures, and providing the on-the-ground capacity to support and facilitate their connection to outside venture capital. As identified in interviews with key stakeholders, there was near consensus that access to capital in the region was a key barrier to the growth of life sciences companies. As more entrepreneurs receive larger pools of funding from coastal VCs, they become more likely to relocate other elements of their business to be closer to their investors and their networks. In addition to growing the pool of venture investors, there is a need to ensure that the Pittsburgh region has more partnerships with these coastal firms to develop the types of relationships and networks locally that can bring in more capital and mentorship.

Across the nation, states are activating capital for startups through the State Small Business Credit Initiative (SSBCI) and other programs. In the Pittsburgh region, this has led to new funding for LifeX and Innovation Works. However, many other states are also using their SSBCI funds and other financial sources to support opportunities across targeted industries or populations. For the Pittsburgh region, this represents a unique opportunity to fund an even greater number of innovative life sciences companies working across data-driven healthcare, connected devices, next-generation therapeutics, and precision medicine.

Potential Action Components:

- **Market the region and develop partnerships with established coastal VC firms.** By developing strategic partnerships with well-established venture capital firms, the startups in the Pittsburgh region have the potential to receive more investment and access to a broader network of investors and mentors. Collaborative events such as pitch days and networking sessions could be organized to facilitate direct interactions between regional entrepreneurs and VC firms.
- **Develop a venture fund for targeted platforms by using state- or federal funds.** The development of new venture funds in the region could allow for critical financial support to reach emerging life sciences companies. This could be an area where the Commonwealth of Pennsylvania can play a pivotal role in moving the needle and growing the pool of venture capital access available in the region. By leveraging programs that are encouraging venture capital access, there are opportunities for

the Pittsburgh region to support the growth of local startups in its targeted platforms (Data-Driven Healthcare and Connected Devices, and Next-generation Therapeutics and Precision Medicine).

- **Explore innovative funding models to encourage innovations that leverage the region's philanthropic resources.** Pittsburgh is among a select set of regions nationwide with a very large and well-funded philanthropic community that is focused on forward-thinking and locally focused topics. Funding models such as impact investing, donor-advised funds, pay-for-success, and social-impact bonding models are all flexible and patient capital options that could be creatively applied to help encourage early-stage innovation. Engaging regional philanthropies and family offices in these funding models can help align their charitable goals with the region's economic development objectives and unlock new sources of funding that complements traditional avenues for venture investment.

What Others Do: University of Minnesota Tech Transfer and Program Related Investments

In the spring of 2020, the University of Minnesota launched a groundbreaking partnership with the Venn Foundation to develop a program-related investment (PRI) model that helps more promising research discoveries make it to market for the benefit of society.³⁹ Because PRIs fund activities where for-profit risk capital funds will not, but where a financial return is still possible, they play an important role in advancing promising discoveries through the commercialization gap.

Through this unique partnership, ANY donor or group of donors can capitalize a PRI to help advance almost ANY University of Minnesota technology toward a license. If the University earns revenue from that technology, it is shared 50/50 with Venn up to a 3X return. The original donors then get to recommend new PRIs or grants. If the institution cannot license the technology, the PRI becomes a normal grant, which limits potential downsides for both parties. So far, the University of Minnesota and the Venn Foundation are working together to match potential donors to promising technology projects, including examples like reversible male contraception and a prognostic test for osteosarcoma.

The Venn Foundation is able to work with public research institution nationwide through this model, working as a syndicator for a PRI for any technology in the institution's pipeline under the same legal framework and with the same financial terms.

Action 3.4: Translate and connect industry needs to educational providers and workforce partners across the educational continuum.

A critical element in advanced industry development is talent, and this is especially true for science- and technology-based industries like the life sciences that deploys an outsized concentration of highly skilled, STEM-related talent that requires postsecondary and advanced degrees and often years of specialized experience requirements.⁴⁰ Discussions with industry highlight strong demand not only for the technical talent for which the region is known, but for a middle-skills workforce to fill critical roles across the industry that will typically require some combination of applied associate degrees or certifications or stackable, industry-recognized credentials.

Workforce development is one area within the ecosystem where the region must continue to be proactive in addressing gaps/barriers to further development. As previously noted, the region is a fast-growing market for life sciences degrees and leads the nation in the share of graduates relative to the size of local industry.⁴¹ The disconnect between the size of the region's life sciences industry and the number of graduates produced by its universities can lead to a mismatch that inherently leads to students seeking employment outside of the region after graduation. A misalignment between the region's workforce and the critical skills needed by industry could result in significant challenges for regional employers. Changing dynamics in the region's life sciences industry could result in a significant number of workers seeking new positions and potentially requiring new skills to acquire new work. Additional efforts may be needed to retain more students in the region after they receive their credentials.

Across the nation, a common challenge, even in leading biosciences hubs, occurs when students are unaware of the varied roles and opportunities across the cluster—from production and logistics to quality control to lab technicians, scientists, software developers, data scientists, engineers and more. The industry has numerous on-ramps for career opportunities. For the Pittsburgh region to advance its life sciences industry forward, it will be critical to have private sector led approaches that build career awareness and enable the industry to meet its workforce and talent demands.

Potential Action Components:

- **Create a full-time position exclusively focused on translating industry needs to educational and training providers.** This position would focus on connecting the life sciences industry with regional skills providers while also ensuring that demand-driven industry needs are those being translated to training programs.
- **Continue to explore the development of various workforce training programs to grow the region's talent position in the life sciences, with a focus on next-generation therapeutics.** It will be important for the region to develop stackable credentials for manufacturing/cGMP, regulatory affairs training programs, and business programs focused on therapeutics and biomanufacturing.

40 TEconomy CSBI Report

41 CBRE, U.S. Life Sciences Talent Trends 2024: <https://www.cbre.com/insights/books/us-life-sciences-talent-trends-2024>

- **Establish a tiered approach with articulation agreements (regional community colleges to universities) and ensure connections.** Continue to explore the creation of a structured framework for articulation agreements that helps facilitate a seamless transition across the region's academic institutions. By establishing a clear pathway for students, these agreements can reduce barriers to academic progression and better connect students with the region's life sciences opportunities.
- **Expand partnerships with Pittsburgh Public Schools and other school districts in the broader region to continue to grow life sciences career pipeline programs and encourage inclusive economic growth.** Collaborating with the region's school systems to organize STEM and job fairs around the life sciences can help to inspire students to pursue careers in the life sciences and ultimately strengthen the local workforce. There is also value in the region's stakeholders continuing to work with regional life sciences companies, educators, and other ecosystem partner organizations to promote career awareness through multiple approaches spanning community events, classroom visits, company tours, lab and other equipment donations for class experiments, mentoring, internships, senior projects and capstones, and other creative approaches.
- **Advance approaches for delivering on-the-job training support and continuing education for next-generation therapeutics workforce.** Identify ongoing programs in the region that best equip professionals with the skills and knowledge needed to meet industry demands.
- **Explore the development of a targeted internship program for data-driven healthcare and next-generation therapeutics opportunities.** The region's unique platforms, and the emerging/ established companies involved, lend themselves well to potential internship programs. By coordinating various healthcare, science, and engineering related interns who are working in the region each year, there are opportunities for talented students to gain experience in the fast-growing sector and build relationships with regional employees. Importantly, this also offers a greater likelihood for longer-term talent attraction and retention.
- **Maintain pulse of workforce dynamics facing the region's life sciences industry.** The region should track alignment of annual industry employment projections in high-priority, high-demand occupations or roles against the regional workforce training and education graduate cohorts in key fields/programs for life sciences companies relative to their expressed needs and workforce gaps. The region should also monitor and track job opening trends across the major life sciences industry subsectors to understand who is hiring, for what skills/roles, and overall trends in volumes to understand real-time demand dynamics for employers and where interventions and additional investments are needed.

What Others Do: Biomanufacturing Training and Workforce Development

The Biomanufacturing Training and Education Center (BTEC) at North Carolina State University is a state-of-the-art facility dedicated to providing hands-on training in biomanufacturing. BTEC is home to more than 77,700 square feet of space, including high-tech classrooms and laboratories equipped with bench-scale and pilot-scale bioprocessing equipment. BTEC offers both students and incumbent workers practical learning opportunities in a simulated cGMP production environment with comprehensive facilities. Close connections with industry and a commitment to providing relevant training using cutting-edge equipment and processes make BTEC an excellent example of best practices in biomanufacturing workforce development and education. BTEC is frequently cited by expanding life sciences companies in North Carolina for its influential role in preparing workers for successful careers.

As an international example, The National Institute for Bioprocessing Research and Training (NIBRT) in Dublin, Ireland, is a world-class facility that further exemplifies best practices in biopharmaceutical manufacturing education and research. By combining world-class facilities, industry-relevant training, and innovative research, NIBRT has positioned itself as a global center of excellence. Established in 2011 through an innovative collaboration between industry, government, and academia, NIBRT offers cutting-edge training solutions and research capabilities to support the growth and development of the biopharma manufacturing industry. NIBRT's comprehensive approach includes short courses, customized industry training, online learning, and academic programs ranging from certificates to master's degrees. To complement this, NIBRT also conducts leading-edge research across multidisciplinary areas such as analytical science, cell and genetic engineering, informatics, and bioprocess engineering, contributing to advancements in biopharmaceutical manufacturing.

Strategy 4: Coordinate and amplify the region's life sciences capabilities to help unify the life sciences ecosystem.

Rationale:

The launch of PLSA is an important first step in the development of a dedicated organization that serves as a life sciences “champion” focused on communicating, coordinating and defining a vision for the overall life sciences industry cluster development. Advancing the region's life sciences industry cluster will need a balanced approach between serving local existing and emerging life sciences companies as well as potential industry partners from outside the region. There is a need for mechanisms to bring together the life sciences industry community to address common problems and create stronger academic-to-industry and business-to-business relationships.

Beyond PLSA, there are multiple current activities to leverage as part of the region's efforts to organize and optimally connect the ecosystem. Pitt and CMU have a strong history of working together, and the emergence of PLSA as a neutral convener of the life sciences cluster marks a historic opportunity for long-time competitors UPMC and AHN to come together around a common vision. There is palpable momentum in the region, as evident by the growing presence of venture activity, various entrepreneurial support programs targeting life sciences companies (such as AlphaLab Health and LifeX), and other efforts to connect the ecosystem through ongoing networking activities in the region (e.g., BioBreakfast, Pittsburgh Tech Council, and InnovatePGH).

Over the years, it is clear the Pittsburgh region has been working to develop a complete ecosystem that is built to support the life sciences sector and encourage entrepreneurship and new business development (Figure 21). This includes numerous organizations that are specifically offering services in the life sciences (as highlighted in blue), as well as others that are covering other elements of the innovation ecosystem (as highlighted in green). Figure 21 shows the intersection between the various providers in the ecosystem (the columns), as well as the various types of ecosystem activities that can help to encourage life sciences industry growth. At a high level, these ecosystem elements include research services, entrepreneurial support, scale-up services, workforce development, and overseeing the strategic direction of the industry.

Figure 21: Pittsburgh Regional Life Sciences Economic Development Ecosystem

Key	Primary Provider	Secondary Contributor
Life Sciences Specific Organization or Dedicated Sector Services Evident		
Ecosystem Element General Technology/Innovative Industries Coverage		

Ecosystem Element	Providers																			
	Sector Businesses	Research Universities	Other Colleges	Community Colleges	Health Systems	UPMC Enterprises	BioForge	PLSA	Innovation Works	AlphaLab Health	LifeX	Pgh Tech Council	Innovate PGH	Catalyst Connection	Swartz Center	PRA	Allegheny Conference	RIDC	BioBreak-fast	Foundations
Strategic Planning for Sector Development																				
Basic Research																				
Applied and Translational Research																				
Technology Transfer and Licensing																				
Piloting and Testing Facilities and Services																				
Business Incubator Facilities and Services																				
Business Accelerator Programs																				
Entrepreneur Education, Mentoring and Advisory Services																				
SBIR/STTR Assistance and Coaching																				
Pre-Seed and Seed Capital Access																				
Venture Capital Access																				
Clinical Trials Services																				
Process Development Services																				
Contract Manufacturing and Scale-up Services																				
Regulatory Affairs Services																				
Office/Lab/Flex Space Strategic Developments																				
Scientific and Technical Workforce Development																				
Manufacturing Workforce Development																				
Sector Diversity, Equity, and Inclusion																				
Networking, Intellectual Exchange and Events.																				
Public Policy and Government Affairs																				
Business Retention																				
Business Attraction & Marketing																				
Community Engagement and Outreach																				
Pharma Coverage																				
Device Coverage																				
Health Tech Coverage																				

Source: TEconomy Partners, LLC

The ecosystem summarized in Figure 21 is significant in terms of both the full coverage it provides of key activities and support services needed for new business venture development and growth, and also for the number of organizations collaborating to provide this complete ecosystem network. Programs cover business mentoring and accelerator services from youth to seasoned professionals and demonstrate significant support for business development to members of minority or disadvantaged communities. Serving the entirety of the Pittsburgh region, it is also a system where entrepreneurs and developing companies benefit by having access to multiple providers, offering choice in where they access capital, mentoring, incubator space, and other services.

With so many players active in the ecosystem, it is apparent that there is a need for improved coordination. Organized and strategic approaches are needed to help secure state and federal funding for collaborative initiatives. Other regions are successfully working together to attract millions of dollars in funding to support their initiatives. However, the Pittsburgh region has faced challenges in fully harnessing its collaborative potential. In other words, there is an opportunity to “Collaborate to Compete” with other regions pursuing the life sciences. It is recommended that the Pittsburgh region pursue four actions as it relates to coordinating and amplifying the region’s life sciences capabilities to help better organize the life sciences supporting ecosystem:

- Action 4.1: Develop a targeted branding/storytelling campaign around region’s life sciences assets and opportunities.
- Action 4.2: Align regional life sciences ecosystem for collaborative strategy implementation (“Collaborate to Compete”).
- Action 4.3: Advocate for life sciences strategy and means to accomplish regional goals.
- Action 4.4: Empower industry-driven points of view on approaching ecosystem gaps.

Action 4.1: Develop a targeted branding/storytelling campaign around region's life sciences assets and opportunities.

With multiple life sciences strengths, it has been difficult for the region to develop a strong brand or identity. Interviews and focus groups with stakeholders indicated a desire for the ecosystem to align across shared strengths, prioritize signature areas, and clearly articulate the region's focus to external and internal audiences.

Developing a strong, ongoing life sciences ecosystem requires that the region sees itself and is seen by others as a dynamic hub: a place with many job opportunities, a constant flow of innovation, and a supportive business environment. To obtain this reputation, competing cities, regions, and states are undertaking branding/marketing campaigns that communicate to key audiences, both internal and external, the depth and breadth of their assets and the unique resources and opportunities that they provide for advancing innovative life sciences companies. The Pittsburgh region needs to develop a targeted branding/storytelling campaign around the region's life sciences assets and opportunities.

Potential Action Components:

- **Integrate the life sciences into ongoing regional branding/storytelling campaigns, emphasizing the unique platforms.** Incorporate life sciences themes into regional storytelling efforts, with a focus on data-driven healthcare and connected devices and next-generation therapeutics and precision medicine. By highlighting these core competencies and innovative platforms, the Pittsburgh region's branding campaign can help position the region as a hub for ongoing investment and interest from relevant stakeholders.
- **Develop an active media presence, highlighting company accomplishments and ecosystem efforts, raising internal awareness of region's life sciences-related entrepreneurial activities while at the same time pursuing a national and international earned-media.** The creation of a robust media presence that can showcase company and research achievements can increase the awareness of the region's life sciences activities. In turn, this could attract external interest and investment in the region's life sciences ecosystem.
- **Encourage ecosystem partners to advance this branding as part of their overall marketing efforts.** The success of a shared brand depends on the input going in and the willingness among community partners to "carry the torch" and tell the story. By motivating ecosystem partners to incorporate the life sciences branding and storytelling into their own marketing strategies, there are opportunities to create a community of promotional partners that are actively sharing the region's story and enhancing its reputation.
- **Generate excitement through in-person events that celebrate innovation and entrepreneurship.** Highlighting and celebrating innovation and entrepreneurship in the life sciences is an important part of ecosystem building, and something that the Pittsburgh region has done consistently in recent years. It is important to continue to develop these celebratory events to create enthusiasm and engagement among stakeholders and continue to drive momentum amongst life sciences initiatives.

Action 4.2: Align regional life sciences ecosystem for collaborative strategy implementation (“Collaborate to Compete”).

As identified through interviews and focus groups, there is a need for greater cross-system collaboration amongst leading stakeholders. This regional alignment will be critical for implementing strategies outlined in this report that require coordination between various stakeholders. Notably, the formalization of partnerships that link organizations in the ecosystem can help the region respond to external pressures and coordinate their resources more effectively.

Potential Action Components:

- **Empower PLSA as a cluster development organization focused on executive-level problem solving and bringing stakeholders together to address ecosystem gaps.** It is important that the region has a lynchpin organization for its life sciences ecosystem that can facilitate collaboration and drive strategic initiatives to strengthen the regional economy. As an empowered cluster development organization, it is especially important for PLSA to:
 - Create a focal point for outreach and information on life sciences companies in the region, their activities, types of workforces, facilities, etc.
 - Promote networking activities, including forums for discussions on common technology areas of interest, business opportunities to partner, business mentoring through peer networks, and updates on state and national policy environment.
 - Identify, communicate, and address common needs of life sciences companies in areas such as workforce development, facility needs, access to specialized shared-use labs, regulatory assistance, and other professional services.
- **Consider developing a multi-party memorandum of understanding (MOU) for the regional life sciences ecosystem.** This could help align the operations and services of the various organizations and identify potential swim-lanes for organizations to navigate. This exercise could also help to uncover gaps in the ecosystem that are worthy of additional attention. The formalization of partnerships through an MOU could help facilitate the pooling of resources, the sharing of data, and the co-development of programs, which in turn can help lead to more efficient service delivery. The collaboration strategies enabled by an MOU can serve as a connective tissue that links organizations in the ecosystem together.
- **Develop a federated governance model to organize strategic initiatives.** Create a governance structure that can organize and oversee recommended strategic initiatives. It will be important to facilitate coordinate efforts, promote a unified approach to ecosystem development, and ensure there is an alignment of objectives across the different stakeholders.

What Others Do: Using a Memorandum for Understanding (MOU) to Align Economic Development

Originally developed as a blueprint with a host of recommendations and ideas to advance the state's economic future, West Virginia Forward has evolved as an unprecedented collaboration among Marshall University, West Virginia University, and the West Virginia Department of Commerce.⁴² Based on the blueprint's findings, the collaboration utilizes a Memorandum of Understanding (MOU) that formalizes the partnership through commitments from each, outlining specific actions and dedicating resources.

Over time, this partnership has developed into a larger, statewide effort to grow West Virginia's economy. Examples of innovative solutions and opportunities include advancing West Virginia's workforce, business climate, educational opportunities, community development, energy sector, cybersecurity, entrepreneurship, and infrastructure.

As another example, the regions of Tulsa, Oklahoma and Northwest Arkansas are collaborating through the "412 Corridor," a partnership formalized by an MOU signed by both state's governors to establish the "Silicon Valley of transportation and logistics."⁴³ This MOU helped cement additional partnerships and carved a path for an NSF Engine proposal known as the Future Logistics and Advanced Mobility Engine (FLAME) led by Tulsa Innovation Labs and Northwest Arkansas Council. The proposal helped further cement partnerships across state boundaries and regulatory agencies to combine and enhance the workforce, research, and commercialization infrastructure.

42 <https://wvforward.wvu.edu/home>

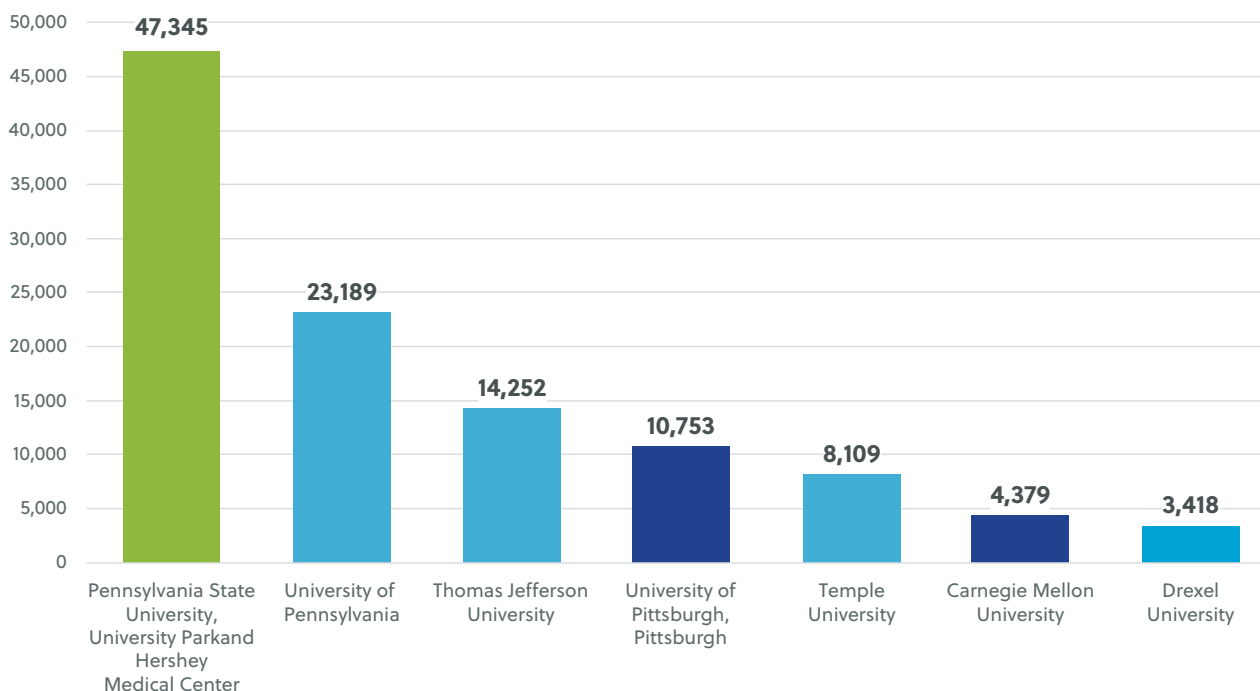
43 <https://heartlandforward.org/case-study/regional-collaboration/>

Action 4.3: Advocate for life sciences strategy and means to accomplish regional goals.

Across the nation, state financial support for strategies and actions has proven to be indispensable for growing life sciences on a regional level. Regions like Boston and the Research Triangle can thank state investments in programs like the Massachusetts Life Sciences Center and NCBiotech for boosting their own life sciences ecosystems. To support the strategic activities identified, state funding will be necessary to help leverage support from regional stakeholders, the private sector, and the philanthropic community (see Appendix B). This will require support for the region to be on-par with that of other regions, if not at a greater level, to overcome past discrepancies between regional size and statewide innovation funding.

An analysis of R&D expenditures from state and local governments shows an outsized preference for Philadelphia-based research universities (Figure 22). Unsurprisingly, Penn State led all of the Commonwealth’s universities in total R&D funding from state and local governments (\$47 million in 2022), a credit to its land-grant mission. However, Pittsburgh’s research universities received just over \$15 million in 2022, an amount that is less than the University of Pennsylvania (\$23 million) and only slightly more than that of Thomas Jefferson University (\$14 million). Other schools like Temple (\$8 million) and Drexel (\$3 million) receive considerable funding from state and local governments for R&D when compared to the Pittsburgh region.

Figure 22: Total R&D From State and Local Government Sources in 2022 (\$, Millions)



Source: TEconomy’s analysis of NSF HERD Data

Several recommended strategic initiatives will require significant funding. In addition to pursuing state funding, it is recommended that the Pittsburgh region leverage local philanthropy and private industry partnerships to implement these strategic opportunities and their affiliated actions.

Potential Action Components:

- **Explore funding from federal and state sources, as well as philanthropic and private industry partnerships, to implement life sciences strategies and affiliated actions.** There is a strong value proposition for supporting the life sciences. The Pittsburgh region should seek diverse funding sources to support the implementation of the actions outlined in this opportunity analysis and ensure comprehensive support for the various life sciences initiatives. This may incorporate two approaches:
 - Encouraging the state to invest on a level and in a manner that really incentivizes the sector (like has been done in North Carolina and Massachusetts. See Text Box.)
 - Organizing the region to pursue major grant opportunities (i.e., federal Tech Hubs, Build Back Better grants, etc.)
- **Leverage Pitt's strong position in NIH funding and team science to support research projects and solicitation of major project grants.** The Pittsburgh region can build on established strengths to enhance overall research capabilities and funding potential. The region's research-intensive universities have deep expertise in securing major investments from DoD, DoE, ARPA-H, and other federal sources.
- **Explore potential for social impact investments given the goal of making therapies more affordable and accessible.** There are many philanthropic opportunities related to improving the accessibility and affordability of new therapies. The region's life sciences platforms are well positioned due to alignment with both financial and societal benefits, which could potentially attract impact investments.
- **Seek in-kind contributions from industry.** There may be opportunities for the region to attract in-kind contributions such as expertise, equipment, or services from local industry stakeholders. There may also be opportunities to engage supporting professional service providers (law, accounting, finance, etc.) as contributors as they will benefit from sector growth.

What Others Do: State Support for Life Sciences Development

In North Carolina, the longest-standing driver of the life-science ecosystem is the 40-year-old North Carolina Biotechnology Center (NCBiotech), a cluster-development nonprofit situated in Research Triangle Park that currently receives about \$17 million in state appropriations annually to advance the sector statewide. NCBio-tech heralds the region's strengths in biomanufacturing and contract research organizations, and it aligns its programs with a development strategy that focuses on physical and technical infrastructure, talent at all levels from K through C-level executives, investment capacity for entrepreneurial companies and technology commercialization, and branding and marketing strategies to promote the region and attract new investment.

North Carolina receives a strong return on its investment in NCBiotech.⁴⁴ For example, the estimated state government revenues generated by active loan recipient companies (through direct, indirect, and induced impacts) totals \$77.0 million, an amount nearly five times greater than the state's investment.

In Massachusetts, the Massachusetts Life sciences Center (MLSC) was created in 2008 and funded at \$1 billion over 10 years. It was renewed for another 10 years in 2018, and discussions are now beginning about a further renewal, branded as "Life sciences 3.0." MLSC certifies life-science participants in nine interrelated incentives, including an investment tax credit, NOL extension, sales-tax exemptions, and other benefits. Among its various other offerings, MLSC also administers an angel investment tax credit available to accredited investors in qualifying companies, as well as subsidized internships at the collegiate and pre-college level with one program emphasizing "data science internships." Since its creation in 2007, the MLSC has strategically deployed approximately \$748 million of investments into the life sciences ecosystem, which in turn has generated \$3.3 billion of leveraged investments and created more than 13,000 jobs in Massachusetts through tax incentive and capital programs.⁴⁵

44 <https://www.ncbiotech.org/sites/default/files/2022-12/TEconomy-NCBiotech%20Evidence%20and%20Opportunity%202022%20%28Full%20Layout%29%20%281%29.pdf>

45 <https://www.masslifesciences.com/about/funding-impact/>

Action 4.4: Empower industry-driven points of view on approaching ecosystem gaps.

For regions seeking to foster a thriving life sciences sector with effective and impactful solutions, developing industry-driven viewpoints is critical to ensuring that initiatives are aligned with the real-world needs and challenges facing industry stakeholders. As the Pittsburgh region advances in new platform areas that are growing quickly, it will be important to be responsive to the needs of the ecosystem, especially as it relates to workforce and talent gaps.

Understanding the specific needs of industry and developing programs to address these needs will help underpin the long-term success of the region's life sciences industry. This helps to ensure that programs are practical and relevant so that resources are effectively allocated to the areas of greatest potential impact. For activities such as talent/workforce development, alignment with industry requirements ensures that the local talent pool possesses the right skills and knowledge that is most valued by local employers.

Overall, enhanced collaboration between industry and healthcare systems, academic institutions, government, and philanthropy can help to encourage a more cohesive and dynamic life sciences ecosystem.

Potential Action Components:

- **Leverage PLSA's Industry Advisory Council as a working group to provide oversight for strategic opportunity analysis implementation.** This advisory board is comprised of representatives from various segments of the life sciences industry to provide ongoing insights and guidance.
- **Explore collaborations between industry and local healthcare systems and research universities.** As the region gains prominence in fields such as data-driven healthcare, connected devices, and next-generation therapeutics, there are opportunities to bridge the gap between academic research and industry needs. The Industry Advisory Council can provide an effective voice for industry when it comes to elements such as joint research initiatives, shared facilities, industry sabbaticals, or commercialization workshops.
- **Empower industry viewpoints in discussions on workforce development.** Workforce development efforts in the life sciences work best when they are demand driven. There is value in having a central resource for addressing the evolving workforce needs of the life sciences industry. Educational programs like customized training programs, apprenticeship networks, or executive offerings for mid-career professionals should be aligned with the needs of industry.

Organizing for Success: An Approach for Execution

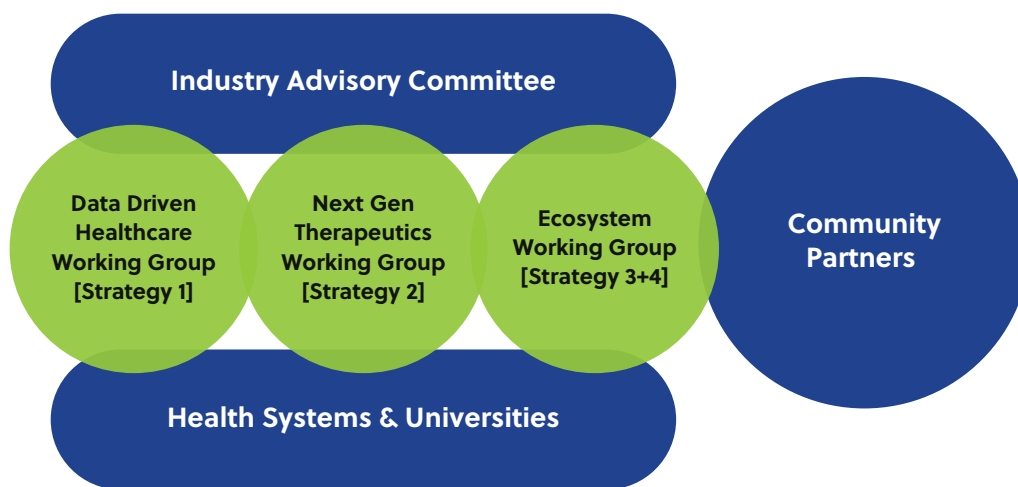
The goal of this strategic opportunity analysis is to identify, in a robust and data-driven manner, differentiated strengths in the Pittsburgh region that can serve as the basis of a global life sciences industry cluster capitalize and to define actions that will enable the region to build this cluster and obtain the economic benefits that result. The analysis found differentiated opportunities in data-driven healthcare and connected devices and next-generation therapeutics and precision medicine and outlined fourteen actions the region can take to address these opportunities.

To deliver on the potential of these platforms, and succeed in undertaking the actions defined herein, it will be critical for the Pittsburgh region and its leading stakeholders across the life sciences ecosystem to work collaboratively to organize and execute on these opportunities.

Organizational Models

The Pittsburgh region has long had many of the right ingredients for a successful life sciences cluster, such as substantial and differentiated life sciences assets and a strong and supportive ecosystem of regional stakeholders. However, a lack of a common vision under which multiple stakeholders could collaborate to advance life sciences has prevented the region from moving to the “next level” in encouraging broad-based economic growth. It is recommended that the region organize around PLSA as a backbone organization for the life sciences and develop working groups to review the opportunity set and define prioritized approaches to addressing the opportunities defined herein (Figure 23). While PLSA will not be responsible for implementing each of the strategies and actions identified throughout this report, it will be necessary for there to be strategic oversight to ensure the appropriate parties and senior stakeholders are at the table.

Figure 23: Organizing to Implement Realization of Regional Life Sciences Opportunities



Source: TEconomy Partners, LLC

To accelerate life sciences economic development, it will be necessary to empower senior leadership, elevate the voices of industry, and direct swim lanes for the regional ecosystem. There is a role for PLSA to serve as a coordinator across each of these priorities by enabling working groups to oversee core elements of the strategy. It is recommended that PLSA fully utilize its industry advisory council (Action 4.4) and convene three working groups to provide strategic oversight.

First, it is recommended that PLSA elevate additional industry voices as part of its role as a cluster development organization. PLSA's industry advisory council is an important first step in this process, and this group should be leveraged as much as possible in the organization's early days and provide oversight into the implementation of strategies and actions. As noted in Action 4.4, it will be critical for the region's life sciences ecosystem to be responsive to the needs of industry. In areas such as workforce development, capital attraction, and facilities access, there are opportunities to engage the private sector to ensure their voices are being empowered in decision making. Empowering more industry voices will involve actively seeking input from a range of companies of various sizes, leveraging industry forums, advisory boards, and other collaborative initiatives that elevate the weight of the sector's voice. Amplifying private sector voices can help the region identify the challenges and opportunities that might otherwise be overlooked.

Given the interdisciplinary nature of the platforms identified, it will be important to engage industry (as well as academia, healthcare systems, and the entrepreneurial and capital communities) in working groups to provide oversight on regional ambitions in data-driven healthcare and connected devices and in next-generation therapeutics and precision medicine. Industry input and investment can be extremely powerful in helping to encourage the long-term success of the actions identified through this report.

It is also recommended that PLSA continue to empower senior leadership at the decision-making level to encourage buy-in. By design, PLSA's board of directors is comprised of high-level individuals who have the capacity to advance strategic initiatives but are not necessarily the highest-level decision makers (i.e., Presidents and CEO's). To engage more senior leadership in the life sciences sector, it will be crucial to create mechanisms for regular interaction between senior leaders, policymakers, and industry voices to best align the local life sciences ecosystem.

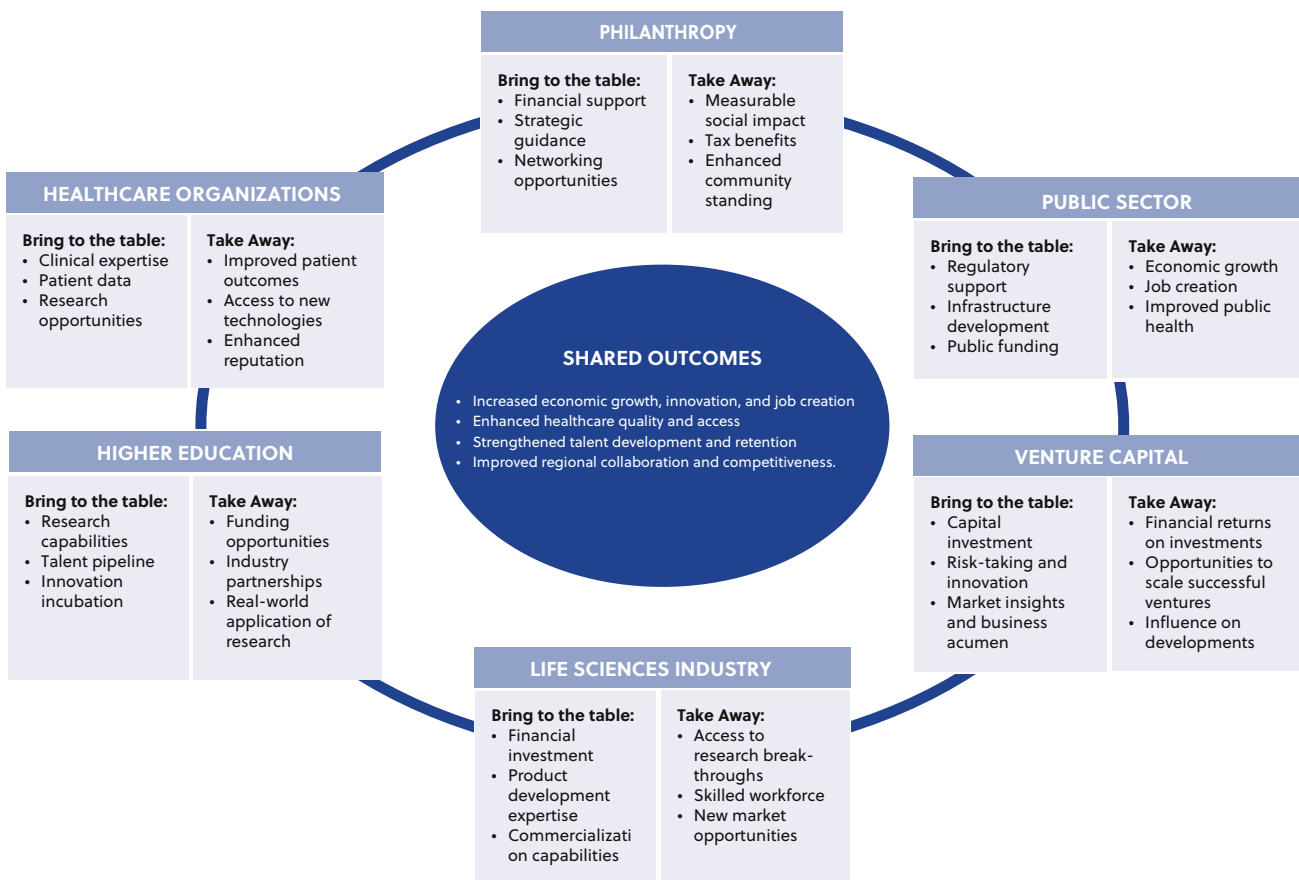
Lastly, it is recommended that PLSA develop a working group around the life sciences ecosystem as a crucial first step in ensuring efficient resource allocation and avoiding the duplication of efforts. By meeting frequently and mapping out the capacities and responsibilities of different stakeholders (i.e., academic institutions, philanthropies, entrepreneurial support organizations, workforce development groups, etc.), there are opportunities for the region to maintain an ongoing understanding of gaps in the ecosystem. Clearly delineating roles and highlighting areas that will continue to need attention can also help the region quickly respond to federal or state competitions for economic development funding (Action 4.3).

Benefits of Shared Investment

A critical element to achieving success will be the capacity of stakeholders to reach consensus on strategic priorities and desired outcomes. Effective communication and management of expectations will be vital. Furthermore, human and financial resources will be essential for these strategic initiatives to flourish. A fundamental factor that can propel this plan’s success is the potential for advantages to accrue for all stakeholders. The strength of a collective approach lies in the ability to ensure that all participants in the alliance are able to reap the rewards of their investments.

As illustrated in Figure 24, the individual contributions and benefits of stakeholders can catalyze greater benefits for the wider ecosystem. For programs such as a flagship initiative around data-driven healthcare and other actions identified that could require shared resources, it is important to understand these shared outcomes for the broader life sciences ecosystem.

Figure 24: Shared Investments and Shared Benefits



Source: TEconomy Partners, LLC

The success of this work will ultimately rest on the ability of the Pittsburgh region to implement it. There is a strong recognition that PLSA can act as a backbone organization to support this ambition, but this will require both investment and patience, together with sustained support from the highest level of leadership within key stakeholder organizations.

Measuring Impacts

Key measures to track the performance of strategic initiatives and potential outcomes into the future should consider industry, platforms, and ecosystem metrics. Examples of potential metrics to measure the impacts of strategies and actions can be found in Table 6.

Table 6: Potential Impact Measures

Category	Ways to Measure
<p>Industry Performance: <i>Growing life sciences companies and jobs</i></p>	<p>Over time track macro, high-level performance across life sciences-specific measures of the region:</p> <ul style="list-style-type: none"> • Level and growth of industry employment, business establishments, and wages. • Level and growth of industry sales/output. • Level and growth of industry productivity, measured as value-added per worker. • Growth in sector contribution to regional GDP.
<p>Platform Performance: <i>Investment in the life sciences</i></p>	<p>Over time track the advancement of each growth opportunity with respect to the levels and growth of progress in Platform Areas:</p> <ul style="list-style-type: none"> • Technology transfer metrics, benchmarked against national averages, and ideally implementing an annual survey to regional research institutions to specifically track life sciences-related commercialization outcomes. • Key productivity measures on regional R&D translation into innovation—life sciences related VC, Angel, and SBIR/STTR awards to regional emerging biosciences companies both overall and relative to the institutional R&D base of expenditures. • Regional startups; venture capital and angel investments (both funding values and deal volumes). • Federal grants and awards related to each area. • Workforce training and education programs established directly related to targeted skills development.
<p>Ecosystem Measures: <i>Recognition as a life sciences cluster</i></p>	<p>Track more micro, performance type measures related to PLSA, for example:</p> <ul style="list-style-type: none"> • Assistance with state life sciences-related economic development recruitment, expansion activities of companies. • Regional life sciences grants, and other funding awarded to cluster organizations and consortia.

Source: TEconomy Partners, LLC



Conclusion

The Pittsburgh region stands at a pivotal moment in its evolution as a leader in the life sciences. With a rich history of medical innovation and strong institutional support from key organizations including Pitt, UPMC, AHN, CMU, and a growing base of life sciences companies, the region is well-positioned to capitalize on its strengths. In particular, there are robust opportunities for focused R&D and cluster development in two arenas that are poised for rapid market growth—data-driven healthcare and connected devices and next-generation therapeutics and precision medicine. However, to fully realize its potential, the region must address existing gaps by developing a cohesive strategy that enhances its life sciences ecosystem. This involves establishing a premier initiative around data-driven healthcare, leveraging the BioForge initiative for advanced therapeutics, and fostering a supportive environment for life sciences companies through talent cultivation and capital attraction. By coordinating capabilities and aligning efforts through collaborative strategies, the Pittsburgh region can transform its academic and research prowess into a world-class life sciences industry cluster, thereby driving economic growth and innovation in the healthcare sector.

Appendix A: Stakeholders Engaged Through One-on-One Interviews and Focus Groups (Alphabetical Order)

- **Jason Baim**, Net Health
- **David Bartlett**, Allegheny Health Network
- **Aaron Brauser**, Realyze Intelligence
- **Quintin Bullock**, Community College of Allegheny County
- **Megan Butler**, LifeX
- **Joe Cardosi**, Free Market Health
- **Julia Chapin**, Abridge
- **Richard Clarke**, Highmark Health
- **Jeffrey Cohen**, Allegheny Health Network
- **Keith Cook**, Carnegie Mellon University
- **Jeanne Cunicelli**, University of Pittsburgh Medical Center Enterprises
- **Evan Facher**, University of Pittsburgh Innovation Institute
- **Robert Ferguson**, Jewish Healthcare Foundation
- **Michael Finke**, M*Modal
- **Ty Gourley**, Hillman Foundation
- **Michael Hufford**, Lygenesis
- **Jeanne Iasella**, Innovation Works
- **Ron Jankowski**, Cook Myosite
- **Chris Johnson**, TeleTracking
- **Jana Kainerstorfer**, Carnegie Mellon University
- **Ketki Karanam**, University of Pittsburgh Medical Center Enterprises
- **Vera Krekanova**, Allegheny Conference on Community Development
- **Edgar Largaespada**, Partner4Work
- **Adrian Lee**, University of Pittsburgh
- **Keith LeJeune**, Allegheny Health Network Research Institute
- **Pam Lewis**, Hillman Foundation
- **Keir Loiacono**, BlueSphere Bio
- **Richard Lordo**, Smith & Nephew
- **Sean Luther**, InnovatePGH
- **Christian Manders**, Promethean Life Sciences
- **Theresa Mayer**, Carnegie Mellon University
- **Richard Neff**, Indiana Regional Medical Center
- **Hooman Rashidi**, University of Pittsburgh
- **Sam Reiman**, Richard King Mellon Foundation
- **Constantino Rodriguez**, ElevateBio
- **Sean Rollman**, ZOLL Life Vest

- **Roni Rosenfeld**, Carnegie Mellon University
- **Jose Sahel**, University of Pittsburgh
- **Russell Schwartz**, Carnegie Mellon University
- **Megan Kahn-Shaw**, Pittsburgh Life Sciences Alliance
- **Anantha Shekar**, University of Pittsburgh
- **George Siddoway**, Bayer
- **Mary Beth Siro**, University of Pittsburgh Medical Center Enterprises
- **Don Smith**, Regional Industrial Development Corporation
- **Bob Starzynski**, Innovation Works
- **Jonathan Steckbeck**, Peptilogics
- **Raymond Vennare**, Predictive Oncology
- **Heidi Ward**, Pitt's Greater Hazelwood Neighborhood Commitment
- **Lisa Witte**, Thermo Fisher Scientific
- **Betty Woo**, Thermo Fisher Scientific
- **Sam Woods Thomas**, Life Sciences Pennsylvania

Strategic Advisory Committee

The following individuals served as members of the Strategic Advisory Committee:

- **Dr. Quintin Bullock**, President, Community College of Allegheny County
- **Ms. Kinsey Casey**, Chief Administrative Officer, University of Pittsburgh BioForge
- **Ms. Jeanne Cunicelli**, President, UPMC Enterprises
- **Dr. Evan Facher**, Vice Chancellor for Innovation and Entrepreneurship, University of Pittsburgh
- **Dr. Ken Gabriel**, Chief Executive Officer, University of Pittsburgh BioForge
- **Mr. Ty Gourley**, Vice President, Hillman Foundation
- **Dr. Vera Krekanova**, Chief Strategy and Research Officer, Allegheny Conference on Community Development
- **Dr. Keith LeJeune**, Senior Vice President, Allegheny Health Network Research Institute
- **Mr. Craig Markovitz**, Entrepreneur in Residence, Carnegie Mellon Swartz University Center for Entrepreneurship
- **Dr. Theresa Mayer**, Vice President for Research, Carnegie Mellon University
- **Dr. Richard Neff**, Chief Medical Officer, Indiana Regional Medical Center
- **Mr. Sam Reiman**, Director, Richard King Mellon Foundation
- **Mr. Sean Rollman**, Vice President and CFO, ZOLL Life Vest
- **Dr. Jose Sahel**, Distinguished Professor, University of Pittsburgh Medical School
- **Ms. Megan Shaw**, President and CEO, Pittsburgh Life Sciences Alliance
- **Mr. George Siddoway**, Senior Director of Medical Devices, Bayer
- **Dr. Jonathan Steckbeck**, CEO and Founder, Peptilogics
- **Mr. Brook Ward**, President, UPMC Washington and UPMC Greene
- **Ms. Lisa Witte**, Senior Vice President, and President Customer Channels Group Thermo Fisher Scientific
- **Dr. Betty Woo**, Vice President and General Manager, Cell and Gene Therapy, Thermo Fisher Scientific

Appendix B: The Role of the Commonwealth of Pennsylvania in Encouraging Life Sciences Economic Development.

Pennsylvania is competing with many of its peer states when it comes to encouraging the development of the life sciences. As noted throughout this report, other states across the nation are making significant investments to grow and scale their life sciences ecosystems. For example:

- The North Carolina Biotechnology Center (NCBiotech), a cluster-development nonprofit situated in the RTP that currently receives about \$17 million in state appropriations annually to advance the sector statewide.
- The Massachusetts Life sciences Center (MLSC) was created in 2008 and funded at \$1 billion over 10 years and was renewed in 2018.

This life sciences opportunity analysis aligns well with the Pennsylvania economic development strategy. The life sciences and robotics and technology were identified by the Shapiro administration as two of the five key industry sectors the Commonwealth wants to target for resources to maximize economic growth, according to its 2024 economic development strategy, its first in nearly two decades. Many of the recommendations included are relevant to the life sciences strategy (e.g., investing in economic growth, making government work at the speed of business, building vibrant and resilient regions). One potential driver of life sciences economic development is rooted in the fourth strategic initiative: “innovate to win, because innovators become entrepreneurs, and new discoveries enable our people and companies to succeed.”

Notable recommended actions within this strategic initiative that align with this life sciences strategic opportunity analysis include:

- **Establish industry-focused startup competitions to source, support, and scale entrepreneurial solutions to pressing challenges facing Pennsylvania industries and governments:** This recommendation aligns with Action 1.1 and the data-driven healthcare initiative’s potential applications to aging care and cybersecurity.
- **Convene Pennsylvania industry leaders and higher education partners to better inform economic policies, retain and attract companies, and promote the creation of new businesses and startups:** This recommendation aligns with many of the actions included herein, most notably Action 1.1 (Build a dominant position in data-driven healthcare innovation), Action 2.3 (Further develop the precision medicine ecosystem and supply chain with targeted business attraction and development efforts), Action 3.4 (Translate and connect industry needs to educational providers and workforce

partners across the educational continuum), and Action 4.4 (Develop industry-driven points of view on approaching ecosystem gaps).

There are three primary ways the Commonwealth can best support life sciences developing in the Pittsburgh region:

1. **Promote and support life sciences as a statewide economic driver.** This includes clearly communicating at a national level that PA is a life sciences hub, and supporting and articulating the region's unique assets. In addition, continuing to support targeted business attraction efforts to attract additional business anchors to SWPA is a core need.
2. **Provide catalytic ongoing investments to support the life sciences (as seen in states like Massachusetts and North Carolina). This includes meaningful financial investment to build additional risk capital and supporting organized regional industry workforce initiatives similar to MassBioEd and NCBiotech Jobs. Specifically, programs that could align well with recommended actions identified through this strategic opportunity analysis include:**
 - o **Develop a New PA Innovation Fund to support large-scale innovation and leverage Pennsylvania's best-in-class research and development assets:** A goal of this fund is to incentivize the deployment of additional private venture capital and positioning Pennsylvania as a national center for innovation, which aligns well with Action 3.3 around attracting new forms of risk capital to the region.
 - o **Develop a new statewide matching program for Small Business Innovation Research (SBIR) awards:** Otherwise known as "America's Seed Fund," SBIR awards are non-dilutive funding provided to emerging companies to commercialize new technologies. Across the nation, many states are supporting entrepreneurs seeking SBIR awards, and there is great value for Pennsylvania to pursue a similar program. For example, the LaunchTN program matches SBIR awards up to \$100,000 for Phase I and \$300,000 for Phase II, while also connecting non-university entrepreneurs to university labs and other mentoring and grant-writing support.
 - o **Increase the percentage of annual Tobacco Settlement payments for health research grants CURE Funding, and modifying conditions of support to also include activities related to commercialization and industry collaboration.** The CURE Program could provide valuable support for new research in the Pittsburgh region that advances the region's platforms in next-generation therapeutics, precision medicine, data-driven healthcare, and connected devices.
3. **Support the planning and execution of the Pittsburgh region's efforts to build a dominant position in data-driven healthcare innovation (Action 1.1).** *As has been seen in other states, the public sector can be a valuable incentive for the region as it begins to organize around a signature platform. Action 1.1 could require substantial capital to ensure the region builds on its capabilities to be a leader in the data-driven health space; supporting this is an area where the Commonwealth can*

directly help the region lead. The Commonwealth can also play a supportive role through a planning grant that can help accelerate the development of this initiative.

Recent initiatives by the administration and legislators such as the SITES program, NOL reform and a continuing decline in CNI are making the business environment more welcoming. Continuing to support, and expand these other programs will help to build innovation across the Commonwealth, including human health innovation in the Pittsburgh region:

- o The **R&D Tax Credit Program** (\$100 million statewide), which provides a tax credit of up to 20 percent of qualifying research and development expenses incurred in the Commonwealth, allowing businesses to reduce their state tax liability and potentially receive a cash refund for unused credits.
- o The **Ben Franklin Technology Partners** program (\$17 million statewide), which funds Innovation Works activities in the region.
- o The **Keystone Innovation Program** (\$15 million statewide). The program supports the Greater Oakland Keystone Innovation Zone, whose boundaries are spread out through key innovation hubs across Pittsburgh and whose incentives can help encourage new business development.
- o The **Pennsylvania Life Sciences Greenhouses**, which funds LifeX.

Appendix C: Key Findings from Topic Modeling Analysis

TEconomy leveraged the Clarivate Analytics Web of Science journal indexing database to analyze life sciences research publications in the Pittsburgh region.

A key finding of this analysis is that the Pittsburgh Region has an exceptionally high concentration of life sciences publications in leading computer science and data science fields (Table A1). Areas of publication strength related to data-driven healthcare and connected devices include robotics and cybernetics, surgical tools and systems, artificial intelligence, advanced analytics and data sciences, and engineering.

Table A-1: Areas of Specialization within Data-Driven Healthcare

Life Sciences Focus Area	Identified Publications (2018-2023)	% More Specialized than USA
Robotics	1,145	95%
Cybernetics	716	57%
Artificial Intelligence	4,706	50%
Software Engineering	1,681	28%
Medical Informatics	684	28%

Source: TEconomy's analysis of data from the Clarivate Analytics' Web of Science publications analysis database

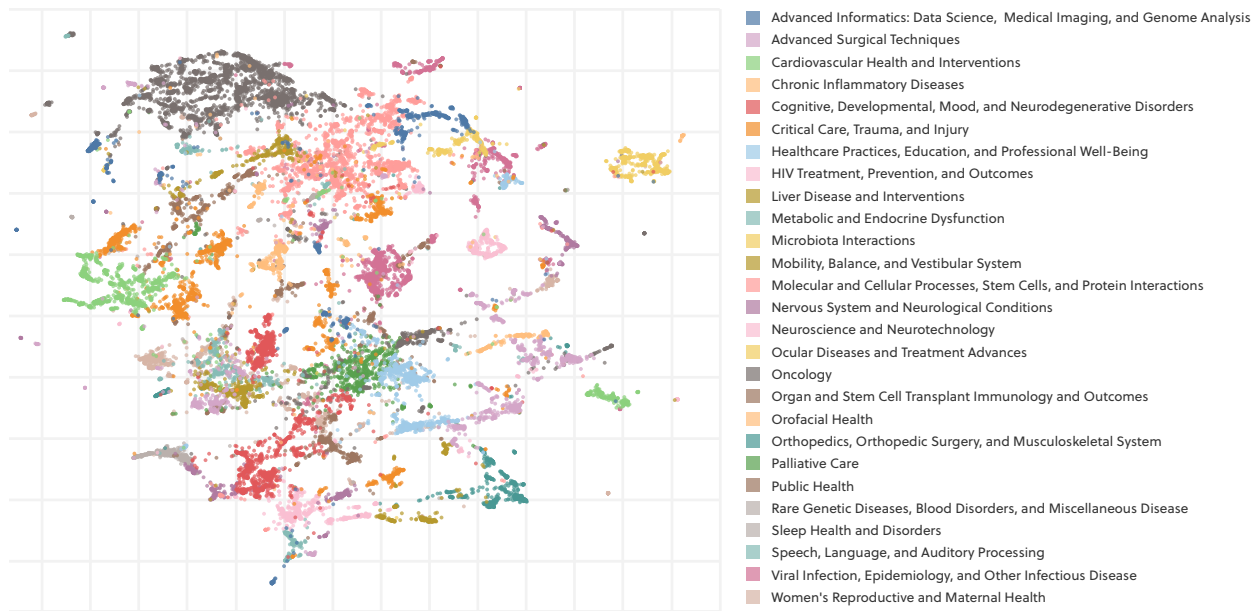
When analyzing new and emerging areas of science and technology such as the life sciences, one of the best ways to understand interdisciplinary research themes is through textual cluster analysis. TEconomy conducted a topic model analysis of research publications that linked individual publications records by their text content using natural language processing approaches to identify detailed topic themes within the body of research activity.

To identify applicable research publications, TEconomy performed a search based on a list of keywords that spanned common life sciences terms. The dataset being examined includes a set of **37,421 research publications** from the Pittsburgh region (2018 to date) captured using life science-related keywords.

To examine the context of research publications activity in further detail and identify cross-cutting thematic areas of focus, TEconomy analyzed the unstructured text content present in publications records. TEconomy employed a topic modeling technique that generates detailed underlying topics present in the research text content. These topics can be grouped into broader research themes that summarize the main focuses of the life sciences field. The text from each research publication's abstract was used to form the data set of unstructured text processed by the analysis. The technique starts by using machine learning algorithms called sentence transformers to convert the unstructured text into numeric representations. Then, a combination of unsupervised clustering and natural language

processing uses these numeric representations to group publications into topics and identify the underlying themes and focuses contained in these topics.

Figure A-1: Thematic Areas Identified by Life Sciences Topic Modeling Analysis



Source: TEconomy's analysis of data from the Clarivate Analytics' Web of Science publications analysis database

The charts on the following pages highlight the leading thematic areas identified through topic modeling.

Figure A-2: Leading Thematic Areas Identified Through Topic Modeling

Oncology (3,707 Publications)

- Immunotherapy in solid tumors; pediatric tumors
- Cancer cell growth; cell therapy and antigen receptor management
- Adjuvant therapy, chemotherapy, and drug outcomes
- Radiation therapy and stereotactic radiosurgery
- Cancer types: breast, lung, lymphoma, leukemia, colorectal, carcinoma, prostate, ovarian and endometrial, melanoma, pancreatic

Molecular and Cellular Processes (2,238 Publications)

- Immune cell regulation in systemic sclerosisMitochondrial dysfunction and cell death
- Stem cell-based regeneration of bone, tissue, and cartilage
- Nitro-fatty acids in vascular, pulmonary, and metabolic health
- Binding and signaling in cell protein interactions
- Pharmacokinetic modeling of drug transporters and drug clearance

Critical Care, Trauma, and Injury (2,100 Publications)

- Acute kidney injury and kidney stones
- Trauma blood transfusion
- Traumatic brain injuries
- Cardiac arrest resuscitation and outcomes with out-of-hospital emphasis
- Management of sepsis and delirium in surgical patients
- Stroke recovery and monitoring of cerebrovascular injuries
- Pediatric tracheal intubation risks

Viral Infection, Epidemiology, and Other Infectious Disease (1,859 Publications)

- Covid-19 characteristics, vaccination, genome, pathogenesis, and impact on emergency care
- Influenza vaccine effectiveness; influenza vaccine and host interactions
- Viral infections (including hepatitis B and C) and encephalitis
- Antifungal treatment
- mRNA therapy and drug and vaccine development; drug-resistant infections

Cognitive, Developmental, Mood, and Neurodegenerative Disorders (1,610 Publications)

- Mental health, PTSD, depression, trauma, anxiety, stress, suicide, ADHD
- Alzheimer's disease and Parkinson's disease cognitive functioning and progression
- Schizophrenia, psychosis, and bipolar disorder

Advanced Surgical Techniques (1,560 Publications)

- Minimally-invasive techniques such as endoscopic skull base surgery, surgery for spinal deformity, fat grafting for cleft palate reconstruction, and liver resection
- Bariatric surgery long-term outcomesRobotic pancreatotomy and esophagectomy
- Frailty in surgery patients, particularly elderly patients

Cardiovascular Health and Interventions (1,523 Publications)

- Ventricular dysfunction and assist devices
- Stroke management
- Outcomes in aortic valve replacement
- Atrial fibrillation and anticoagulation outcomes
- Pulmonary arterial hypertension

Women's Reproductive and Maternal Health (1,263 Publications)

- Adverse pregnancy outcomes
- Menopause and cardiovascular health
- Surgical management of pelvic organ prolapseIntimate partner violence
- Sexual and reproductive health
- Endometriosis and PCOS

Healthcare Practices, Education, and Professional Well-Being (1,119 Publications)

- Prescribing patterns and stewardship
- Training and career development
- Work-life balance and burnout

Advanced Informatics: Data Science, Medical Imaging, and Genome Analysis (922 Publications)

- Medical imaging, neuroimaging, microscopy, and deep learning for image segmentation
- Analyzing clinical data and pharmaceutical processes through predictive modeling and natural language processing
- DNA sequencing, genome analysis using advanced statistical methods, gene editing, and genetic code expansionProtein and drug discovery using deep learning

Orthopedics, Orthopedic Surgery, and Musculoskeletal System (901 Publications)

- Surgical outcomes in ACL reconstruction, rotator cuff surgery, hip arthroscopy, etc.
- Foot and ankle strength and deformitiesOsteoporosis and fracture management



Source: TEconomy's analysis of data from the Clarivate Analytics' Web of Science publications analysis database.

Figure A-3: Secondary Thematic Areas Identified Through Topic Modeling

Palliative Care (896 Publications)

- Implementation and training
- Comprehensive care and medication management
- Needs of family caregivers

Nervous System and Neurological Conditions (855 Publications)

- Neurogenic bladder dysfunction
- Drug addiction and withdrawal
- Epilepsy treatment and monitoring
- Neurodevelopmental disorders

Mobility, Balance, and Vestibular System (814 Publications)

- Activity and mobility in older adults
- Concussion management and sports medicine
- Vestibular disorders and rehabilitation
- Postural control with emphasis on elderly populations

Public Health (804 Publications)

- Alcohol and drug use patterns
- Occupational risks, air pollution, and climate change
- Dietary intake and food insecurity

Neuroscience and Neurotechnology (782 Publications)

- Visual cortex studies
- Neural electrode technology
- Brain-computer interfaces
- Imaging and inertial sensors

Chronic Inflammatory Diseases (674 Publications)

- Asthma and pulmonary disease
- Inflammatory bowel disease
- Psoriasis, lupus, and dermatomyositis

Ocular Diseases and Treatment Advances (658 Publications)

- Corneal outcomes from treatment of ocular disorders
- Corneal transplants and tissue generation
- Age-related macular degeneration treatment
- Keratitis and other infections

Organ and Stem Cell Transplant Immunology and Outcomes (642 Publications)

- Outcomes in liver, intestinal, other organs, and stem cell transplants
- Immunological factors in organ transplant rejection

Metabolic and Endocrine Dysfunction (514 Publications)

- Diabetes management, pancreatitis, and thyroid function

Sleep Health and Disorders (511 Publications)

- Quality, duration, and neurobiology
- CPAP treatment of obstructive sleep apnea

HIV Treatment, Prevention, and Outcomes (461 Publications)

- HIV prevention, persistence, and antiretroviral therapy
- Cardiovascular health in HIV patients

Liver Disease and Interventions (351 Publications)

- Hepatocyte-driven liver regeneration
- Alcoholic liver disease
- Pediatric cholestatic liver disease
- Liver fibrosis

Speech, Language, and Auditory Processing (271 Publications)

- Aphasia
- Management of hearing loss; speech challenges in children with impaired hearing

Microbiota Interactions (265 Publications)

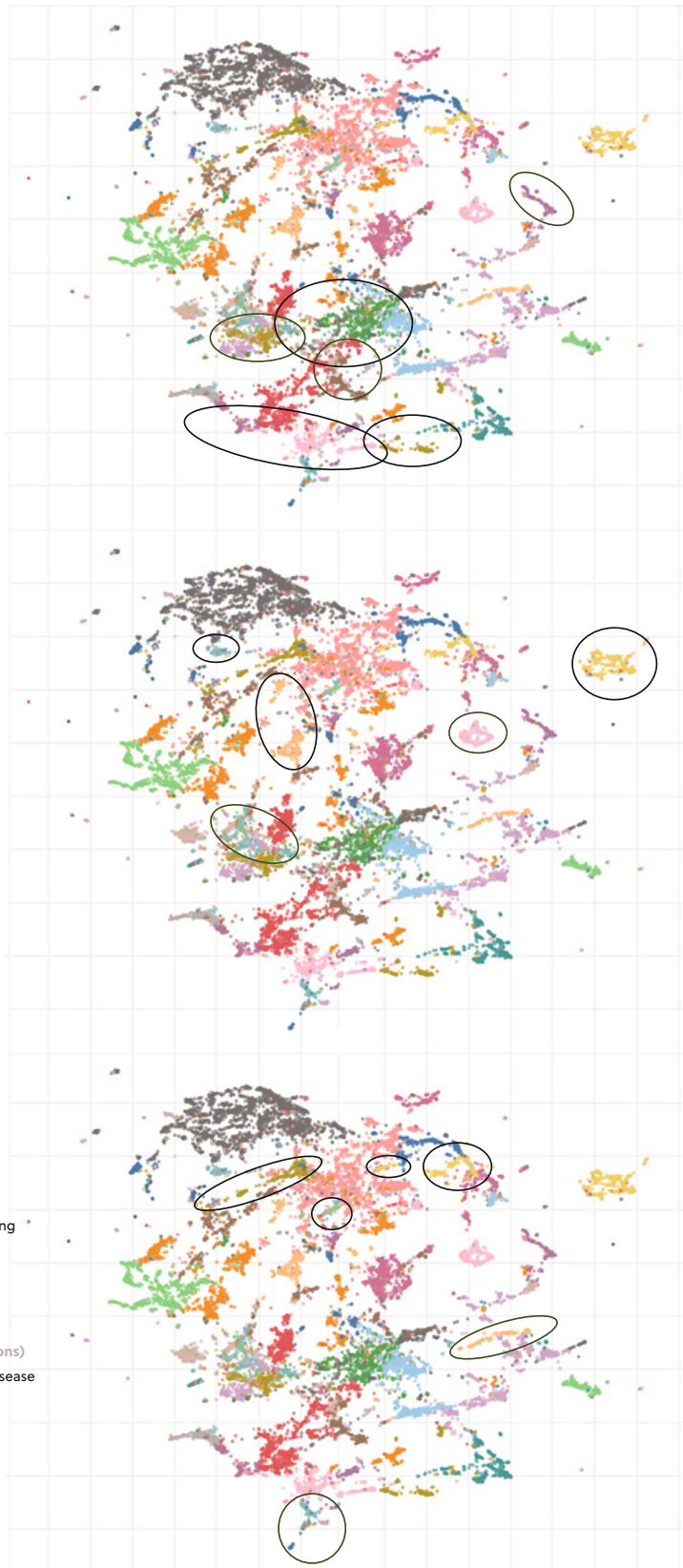
- Gut microbiome diversity
- Phage therapy
- Floral microbiomes and crop productivity

Rare Genetic Diseases, Blood Disorders, and Miscellaneous Disease (237 Publications)

- Blood disorders including hemophilia, Von Willebrand disease, and sickle cell disease
- Muscular dystrophy
- Pediatric Lyme disease
- PKU

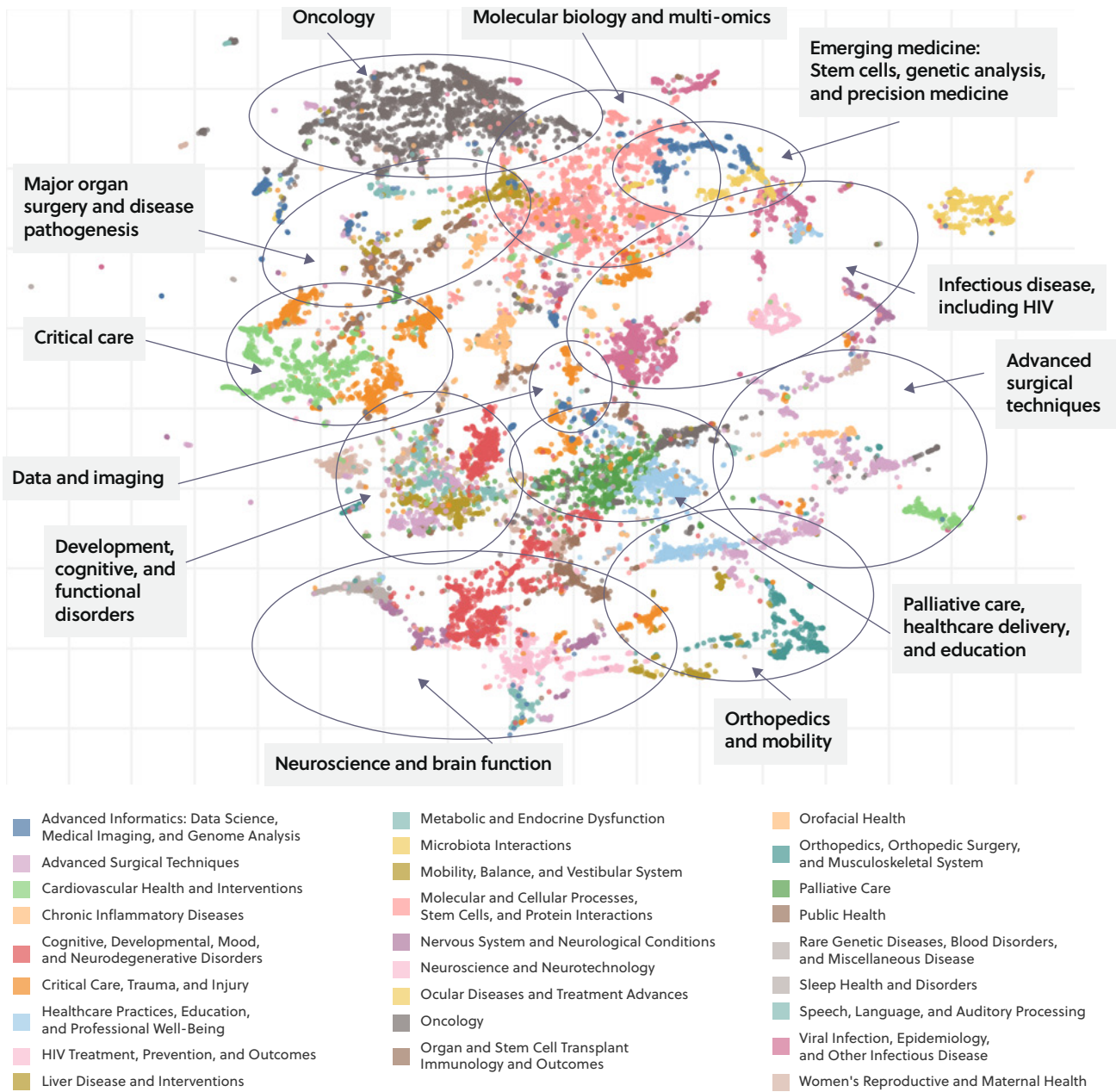
Orofacial Health (213 Publications)

- Dental and oral health
- Genetic factors in orofacial clefts and facial variation



Source: TEconomy's analysis of data from the Clarivate Analytics' Web of Science publications analysis database

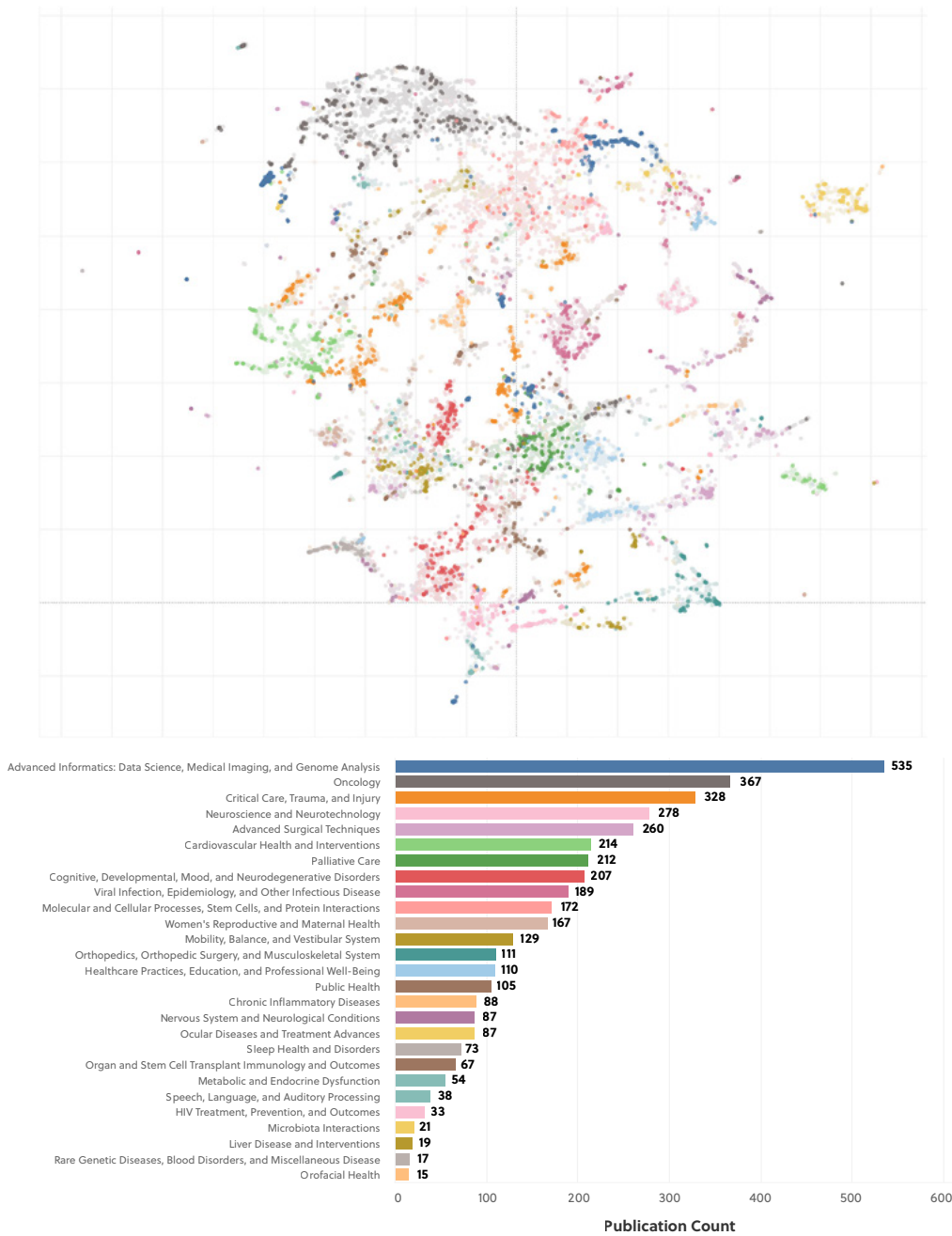
Figure A-4: Life sciences Publications by Broad Thematic Area



Using publications identified through TEconomy's advanced analytics, TEconomy analyzed technology-focused publication areas to highlight the "embeddedness" of tech across the life sciences publishing themes (Figure A5). While there are 535 publications classified in advanced informatics, the most of any thematic area, this represents just a small subset of the many themes where technology is embedded across regional life sciences. Most notably, technological embeddedness exists across oncology (367 publications), critical care (328 publications), neuroscience and neurotechnology (278 publications), and in advanced surgical techniques (260 publications). Within the advanced informatics area, notable for the Pittsburgh region include:

- Imaging, neuroimaging, microscopy, and deep learning for image segmentation.
- Analyzing clinical data and pharmaceutical processes through predictive modeling and natural language processing.
- DNA sequencing, genome analysis using advanced statistical methods, gene editing, and genetic code expansion.
- Protein and drug discovery using deep learning.

Figure A-5: Technology and Data-Science Focused Publications Based on Keywords



Source: TEconomy's analysis of data from the Clarivate Analytics' Web of Science publications analysis database

What these data show is the cross-cutting emerging ubiquity of data as a driver of health and life sciences research and innovation. Convergence is obviously already happening in the Pittsburgh region, a characteristic that can be further built-upon and strategically encouraged as the basis for transformational economic advancement.

