TECHNICAL APPENDIX

Leveraging the Phoenix Region's Bioscience Assets for Sustained Economic Growth:

Identifying Growth Opportunities
for the Region and its Bioscience Hubs,
led by the Phoenix Bioscience Core

TECONOMY
PARTNERS LLC

Technical Appendix: Details of Major Analyses Informing the Line-of-Sight to Growth Opportunities

Advancing industry cluster development in today's global, knowledge-based economy requires identifying specific niches or market opportunities in which a region can differentiate itself and build specialized expertise to be a world leader. The bioscience industry cluster, in particular, comprises a broad and highly diverse market for goods and services spanning multiple industries and technologies that allow states and regions to find specific areas of focus aligned with their unique strengths.

TEConomy utilized its "line-of-sight" assessment to identify growth opportunities in the biosciences for Greater Phoenix,[1] the Phoenix Bioscience Core (PBC), and to inform other place-based developments in the region to identify three growth opportunity areas including:

- **Precision Oncology/Medicine**—represents an area of specific focus by Arizona over the past 20 years to leapfrog other more established states in bioscience development to be a leader in the emerging genomics revolution that is reshaping the practice of medicine. The Phoenix region has benefitted from substantial investments to possess a significant depth of research assets spanning multiple institutions that has led to a number of high-growth startups in molecular diagnostics able to attract out-of-state industry investment and position the Phoenix region as a fast-growing center for precision molecular diagnostic labs. Today, the industrial focus is primarily on oncology diagnostics markets and product innovations, but this area represents a legitimate opportunity to ultimately serve numerous end markets and disease areas.

- **Digital Health, WearTech, and Other MedTech**—represents a dynamic, rapidly emerging area in which the region is seeing strong startup and entrepreneurial activity as well as a cadre of existing, growing medical device companies amidst the broader trend toward the "digital transformation" of healthcare with the ongoing convergence of software, hardware, AI, and regional strengths in microelectronics and broader tech industry.

- **Translational Neurosciences**—represents a distinctive area of strength for the Phoenix region in biomedical research, clinical expertise and infrastructure, and translational research found across multiple institutions, with significant ongoing investments being made. This is a distinct and differentiated opportunity area for Greater Phoenix in which it stands out nationally and globally, but it is still an emerging one in industry development, with promising signs among emerging companies.

The line-of-sight approach considers and seeks to align both the "*market pull*" of bioscience industry development and the "*technology push*" of industry-facing research capabilities and competencies at the region's anchor institutions to identify growth opportunities unique to the Greater Phoenix region. The approach leverages and incorporates traditional industry targeting analysis—detailed examinations of trends and the sector's competitive position in its size, relative concentration, and growth—yet it recognizes that this largely illuminates where the regional

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[1] The Greater Phoenix region is defined in this study to align with the metropolitan statistical area (MSA) definition set by the federal Office of Management and Budget to include Maricopa County and Pinal County.

industry has been. Examinations of the recent past are useful, but not sufficient for understanding forward-looking growth opportunities. It is therefore essential to understand where the region has the capacity to grow and to leverage its comparative advantages by leveraging core research competencies and insights on industry innovation activities and investments. All of this must take a forward-looking perspective toward high-growth market opportunities. This approach to strategic alignment and targeting of high potential growth opportunities in the biosciences is shown in Figure A1.

Figure A1: Line-of-Sight Assessment Approach for Identifying Greater Phoenix's Bioscience Growth Opportunities
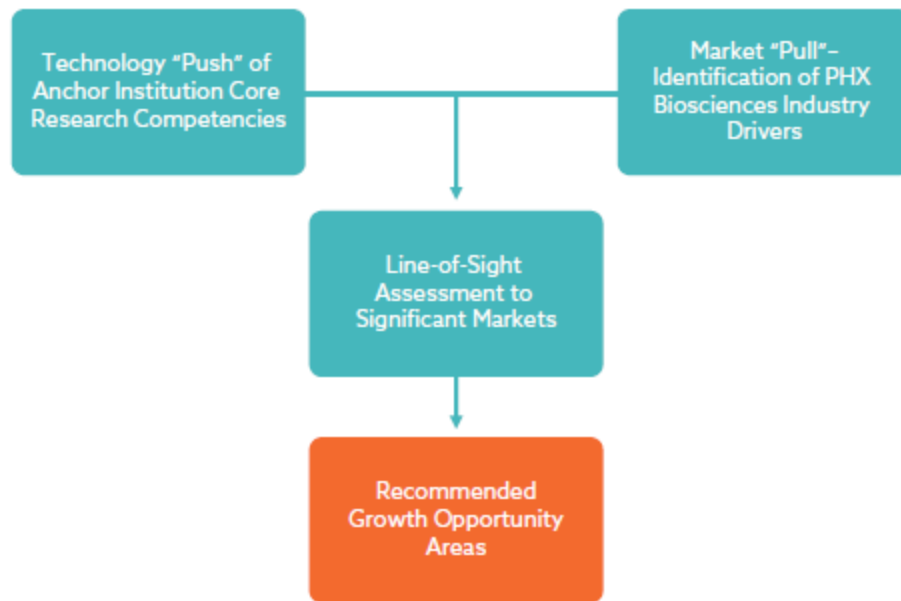
Areas where the Phoenix Region and the Phoenix Bioscience Core have real, differentiating potential.

The line-of-sight assessment examines and combines many measures to gauge the depth and breadth of capacities found in Greater Phoenix and the PBC across bioscience research, innovation and industry trends. This technical appendix provides more details on major data analyses undertaken to identify growth opportunities that were not fully presented in the main report, including:

- For technology push, we present the detailed findings of the research publications analysis and clinical trials activities.

- For market pull, we present the detailed findings of bioscience industry position and performance trends, patent analysis, and venture capital investments.

Technology Push: Details of Analysis of Peer-Reviewed Regional Research Publications

To better understand the distinct strengths and specializations present across the base of regional research activity, TEConomy conducted an analysis of research publications generated by authors in the Greater Phoenix region that represent a critical mass of activity that can support industry-facing growth opportunities. Authors at regional research institutions generated more than 31,200 peer-reviewed publications in all research fields from 2019 through 2023, of which over 15,200 publications were focused in bioscience-related disciplines related to clinical, biomedical, biological sciences, and healthcare research. Leading research fields, the Greater Phoenix region's share of statewide publishing activity, and the region's specialization[2] in life sciences fields are presented in Table A1.

Table A1: Leading Bioscience Fields in Greater Phoenix Research Publishing Activity, 2019-2023 (Includes Fields with at Least 100 Publications)

Research Discipline	Number of Publications	Share of Total Arizona Activity	Publishing Specialization Index
Clinical Neurology	2,107	82.2%	2.45
Surgery	1,717	76.5%	1.63
Oncology	1,561	71.4%	1.47
Neurosciences	1,140	67.3%	1.08
Radiology, Nuclear Medicine, & Medical Imaging	750	69.9%	1.33
Medicine: General & Internal	711	64.8%	1.14
Biochemistry & Molecular Biology	677	54.6%	0.60
Cardiac & Cardiovascular Systems	632	64.0%	1.08
Orthopedics	536	82.8%	1.40
Pharmacology & Pharmacy	529	51.3%	0.71
Gastroenterology & Hepatology	517	81.7%	1.89
Pediatrics	509	73.4%	0.90
Medicine: Research & Experimental	468	67.0%	0.86
Hematology	463	77.4%	1.55
Immunology	460	59.1%	0.69
Genetics & Heredity	459	58.4%	0.93
Health Care Sciences & Services	426	59.2%	0.94
Biology	417	55.4%	1.15
Cell Biology	382	57.9%	0.57
Endocrinology & Metabolism	361	68.0%	0.99
Psychiatry	358	67.8%	0.70

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[2] The publishing specialization index compares the share of all publishing activity in a given field relative to the share of publishing activity in that field nationally; fields with a specialization index greater than 1.2 are considered to have a high level of regional specialization in their publishing volume.

Research Discipline	Number of Publications	Share of Total Arizona Activity	Publishing Specialization Index
Microbiology	341	41.7%	0.64
Nutrition & Dietetics	302	69.9%	1.06
Biotechnology & Applied Microbiology	292	60.8%	0.82
Respiratory System	287	52.6%	1.17
Engineering: Biomedical	286	57.1%	0.73
Peripheral & Vascular Disease	277	62.4%	1.10
Obstetrics & Gynecology	274	69.4%	0.91
Veterinary Sciences	266	70.6%	0.94
Rehabilitation	259	62.9%	1.44
Transplantation	256	76.4%	2.01
Critical Care Medicine	255	58.2%	1.55
Urology & Nephrology	247	71.6%	0.93
Pathology	240	78.4%	1.38
Infectious Diseases	224	49.2%	0.54
Dermatology	223	62.3%	1.23
Otorhinolaryngology	219	75.3%	1.20
Biochemical Research Methods	216	56.4%	0.62
Geriatrics & Gerontology	216	63.2%	1.14
Mathematical & Computational Biology	205	63.1%	0.94
Nursing	200	46.4%	0.69
Dentistry & Oral Surgery Medicine	188	91.3%	1.21
Physiology	178	45.3%	0.79
Anesthesiology	163	73.4%	1.48
Virology	153	58.4%	0.90
Health Policy Services	135	54.4%	0.70
Medical Informatics	134	59.6%	0.82
Biophysics	133	56.4%	0.73
Neuroimaging	131	67.2%	1.35
Toxicology	124	13.1%	0.64
Ophthalmology	124	59.6%	0.60
Substance Abuse	118	65.6%	0.82
Emergency Medicine	115	56.7%	0.93

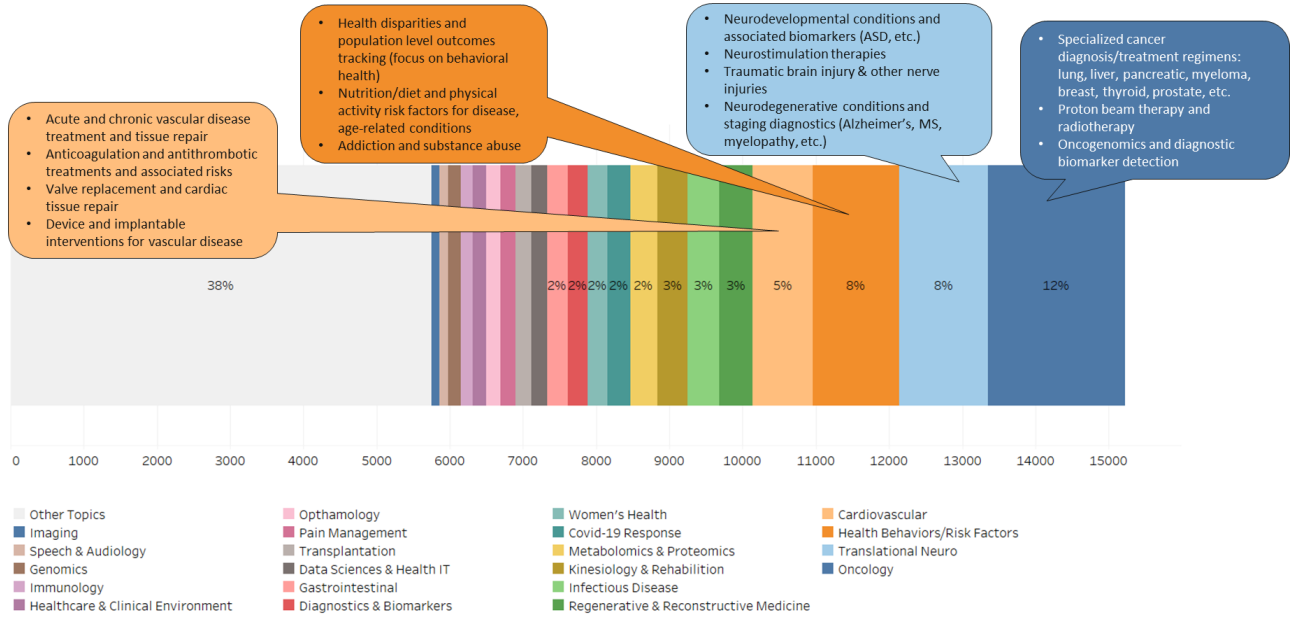Source: TEConomy Partners' analysis of Clarivate Web of Science data.

Notably, the Great Phoenix region accounts for significant shares of the state's total bioscience-related publishing activity and demonstrates several specialized areas of activity. In particular, various fields focused on neurology and neurosciences, surgery and orthopedics, and oncology demonstrate both a high volume of activity as well as high levels of regional specialization.

While research disciplines can be illustrative of the state's critical mass in broad areas of science, today's institutional research models emphasize multidisciplinary research that often combine the expertise of multiple faculty across multiple research areas to advance translational work, a perspective not easily or effectively captured using publications counts. To examine the context of research publications activity through the lens of its specific applied areas of impact and identify cross-cutting thematic areas of focus within publications, TEConomy analyzed the unstructured text content present in publications records using natural language processing (NLP) algorithms to identify detailed topic themes within the body of research activity. This type of thematic analysis uses machine learning algorithms to identify topics (or themes) that are "latent" within the underlying vocabulary of a set of text data using a combination of natural language processing, embedding, and unsupervised clustering methods. The descriptive text content from research publications records present in titles, abstracts, and author-generated keyword descriptors was used to form the data set of unstructured text processed by the analysis. This text content is processed by topic modeling algorithms to generate detailed underlying thematic areas of focus present in the text content which can then be grouped into broad, higher level research themes.
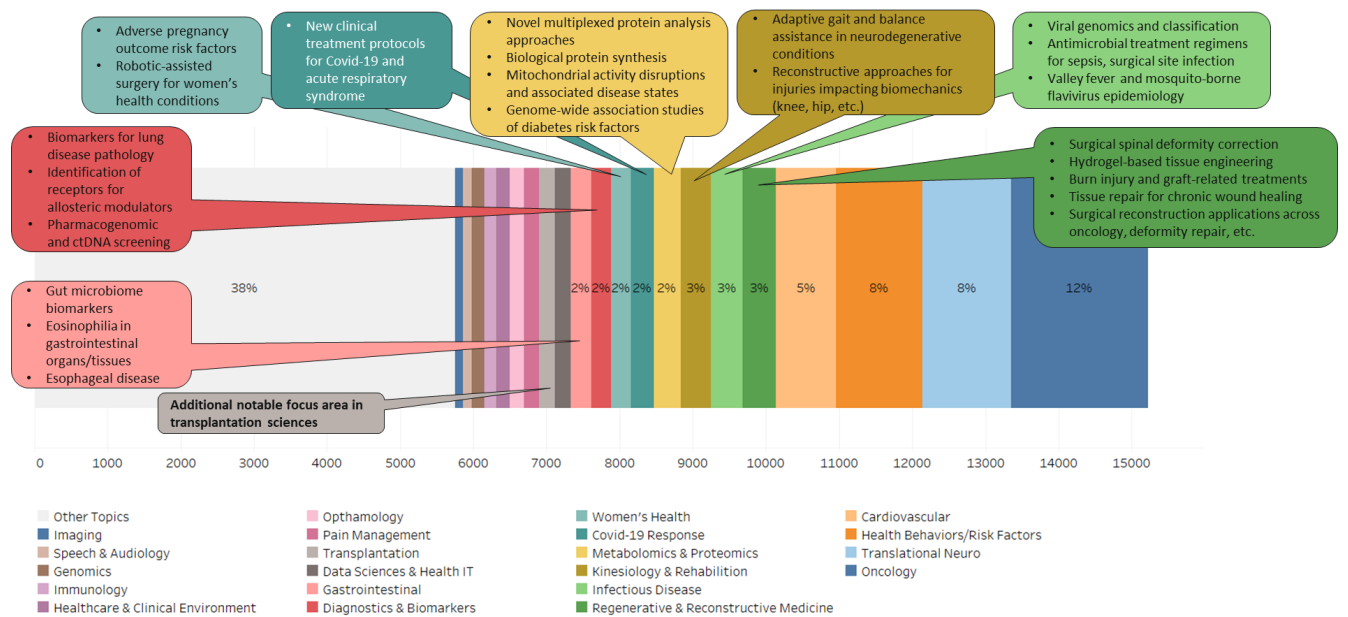
The results of the analysis of the more than 15,000 Greater Phoenix-authored bioscience research publications from 2019 through 2023 identified 100 topics, which were further grouped into 22 higher level areas of thematic critical mass focused on research competencies encompassing 62% of the total publication records content. The remaining 38% of text content was focused on other topics not relevant to bioscience research themes such as professional education and training. Figure A2 below shows these key thematic areas identified within bioscience research publication records with Greater Phoenix authors, with areas demonstrating at least a 2% prevalence within broader themes highlighted and examples of leading detailed topic areas within these areas listed.

Figure A2: Main Research Competencies Identified from Topic Modeling of Greater Phoenix Bioscience Research Publications, 2019-2023

Detailed topic focus areas with >=5% prevalence identified in potential line of sight alignment areas

- Acute and chronic vascular disease treatment and tissue repair
- Anticoagulation and antithrombotic treatments and associated risks
- Valve replacement and cardiac tissue repair
- Device and implantable interventions for vascular disease

- Health disparities and population level outcomes tracking (focus on behavioral health)
- Nutrition/diet and physical activity risk factors for disease, age-related conditions
- Addiction and substance abuse

- Neurodevelopmental conditions and associated biomarkers (ASD, etc.)
- Neurostimulation therapies
- Traumatic brain injury & other nerve injuries
- Neurodegenerative conditions and staging diagnostics (Alzheimer's, MS, myelopathy, etc.)

- Specialized cancer diagnosis/treatment regimens: lung, liver, pancreatic, myeloma, breast, thyroid, prostate, etc.
- Proton beam therapy and radiotherapy
- Oncogenomics and diagnostic biomarker detection

38%   2%2%2%2% 2% 3% 3% 3%   5%   8%   8%   12%

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000

Legend:
- Other Topics
- Opthamology
- Women's Health
- Cardiovascular
- Imaging
- Pain Management
- Covid-19 Response
- Health Behaviors/Risk Factors
- Speech & Audiology
- Transplantation
- Metabolomics & Proteomics
- Translational Neuro
- Genomics
- Data Sciences & Health IT
- Kinesiology & Rehabilitation
- Oncology
- Immunology
- Gastrointestinal
- Infectious Disease
- Healthcare & Clinical Environment
- Diagnostics & Biomarkers
- Regenerative & Reconstructive Medicine

Detailed topic focus areas with >=2% prevalence identified in potential line of sight alignment areas

- Adverse pregnancy outcome risk factors
- Robotic-assisted surgery for women's health conditions

- New clinical treatment protocols for Covid-19 and acute respiratory syndrome

- Novel multiplexed protein analysis approaches
- Biological protein synthesis
- Mitochondrial activity disruptions and associated disease states
- Genome-wide association studies of diabetes risk factors

- Adaptive gait and balance assistance in neurodegenerative conditions
- Reconstructive approaches for injuries impacting biomechanics (knee, hip, etc.)

- Viral genomics and classification
- Antimicrobial treatment regimens for sepsis, surgical site infection
- Valley fever and mosquito-borne flavivirus epidemiology

- Biomarkers for lung disease pathology
- Identification of receptors for allosteric modulators
- Pharmacogenomic and ctDNA screening

- Surgical spinal deformity correction
- Hydrogel-based tissue engineering
- Burn injury and graft-related treatments
- Tissue repair for chronic wound healing
- Surgical reconstruction applications across oncology, deformity repair, etc.

- Gut microbiome biomarkers
- Eosinophilia in gastrointestinal organs/tissues
- Esophageal disease

Additional notable focus area in transplantation sciences

38%   2%2%2%2% 2% 3% 3% 3%   5%   8%   8%   12%

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000

Legend:
- Other Topics
- Opthamology
- Women's Health
- Cardiovascular
- Imaging
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- Covid-19 Response
- Health Behaviors/Risk Factors
- Speech & Audiology
- Transplantation
- Metabolomics & Proteomics
- Translational Neuro
- Genomics
- Data Sciences & Health IT
- Kinesiology & Rehabilitation
- Oncology
- Immunology
- Gastrointestinal
- Infectious Disease
- Healthcare & Clinical Environment
- Diagnostics & Biomarkers
- Regenerative & Reconstructive Medicine

Source: TEConomy Partners' analysis of Clarivate Web of Science data.

The results of the topic modeling analyses affirm several key areas of research competency that emerge from research publishing activity:

- A focus on specialized oncology diagnostics and treatments leveraging oncogenomics and biomarker detection.
- A unique area of activity around translational neurosciences combining diagnostic, disease pathogenesis, and interventional approaches (focused on neurostimulation and devices).
- Population health risk factor and disparities topics supported by significant population health data gathering and management efforts.
- Interventional treatments for acute and chronic vascular disease focused on regenerative medicine and implantable device approaches.
- A variety of themes active in "multi-omics" supporting capabilities including diagnostics development, biological compound synthesis, and biomarker identification characterization.
- A variety of additional focus areas to cardiovascular medicine leveraging surgical interventions, tissue engineering, and medical device platforms.
- A notable and unique focus area in transplantation sciences and management of associated immunological effects on patients.

Technology Push: Details of Analysis of Regional Clinical Trials Activity

To understand and examine the context of clinical research excellence and activity being advanced within the Greater Phoenix bioscience research ecosystem and to identify potential connections to key research competencies, TEConomy examined 5,044 clinical trials records representing all trials with a start date of 2019 or later that had at least one trials site in the Greater Phoenix region, inclusive of all active and ongoing trials. In analyzing clinical trials data, it is important to identify the phase of clinical trials with earlier phases representing closer connections to translating research into clinical outcomes.

As shown below in Figure A3, interventional trials activity (i.e. non-observational trials protocols that involve interventions with drugs, devices, or other interventions to treat medical conditions) is focused on industry-led, later stage trial types. Interventional trials with a Greater Phoenix-based principal investigator or study chair represent just 7% of all trials and were more focused on device-based interventions (which do not have a trial phase) as opposed to other therapeutic intervention types.

Figure A3: Summary of Interventional Clinical Trials Activity at Sites in the Greater Phoenix Region by Lead Sponsor Type, 2019-present
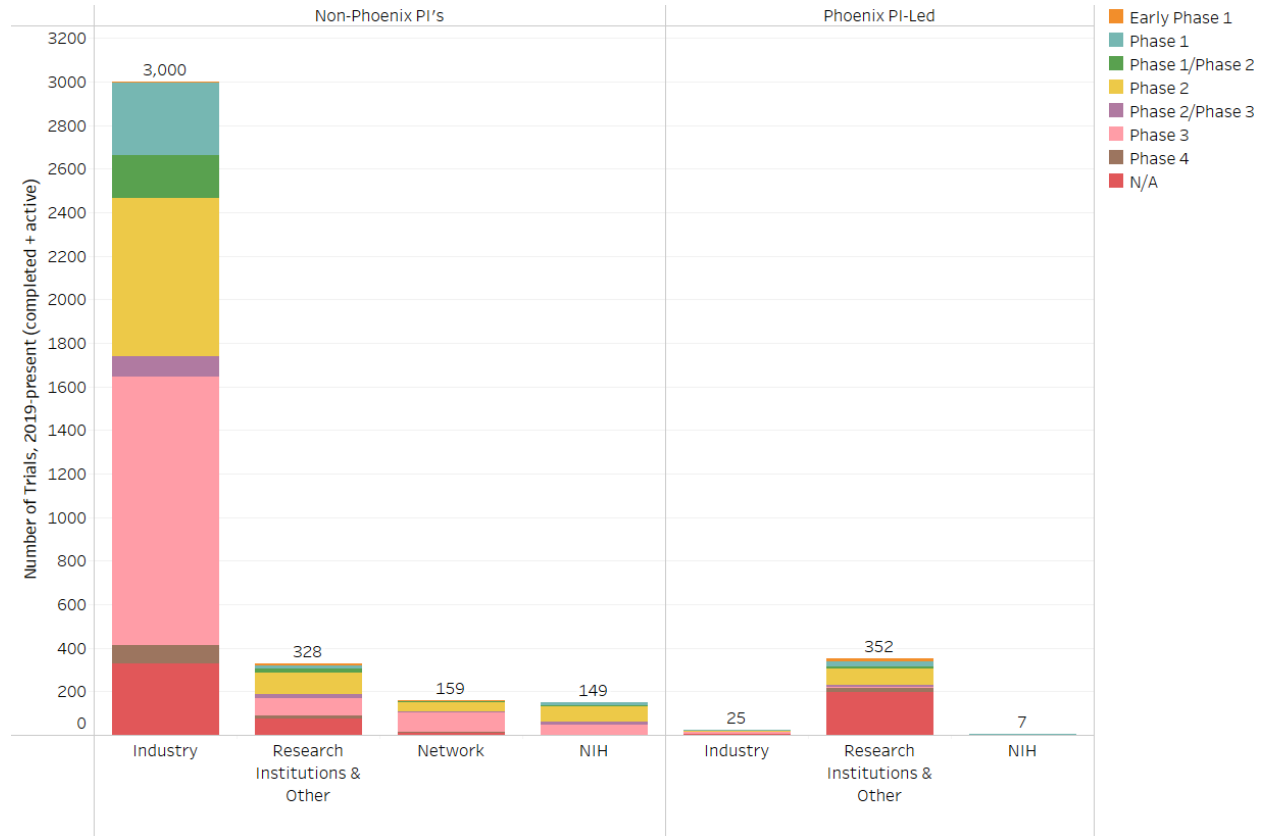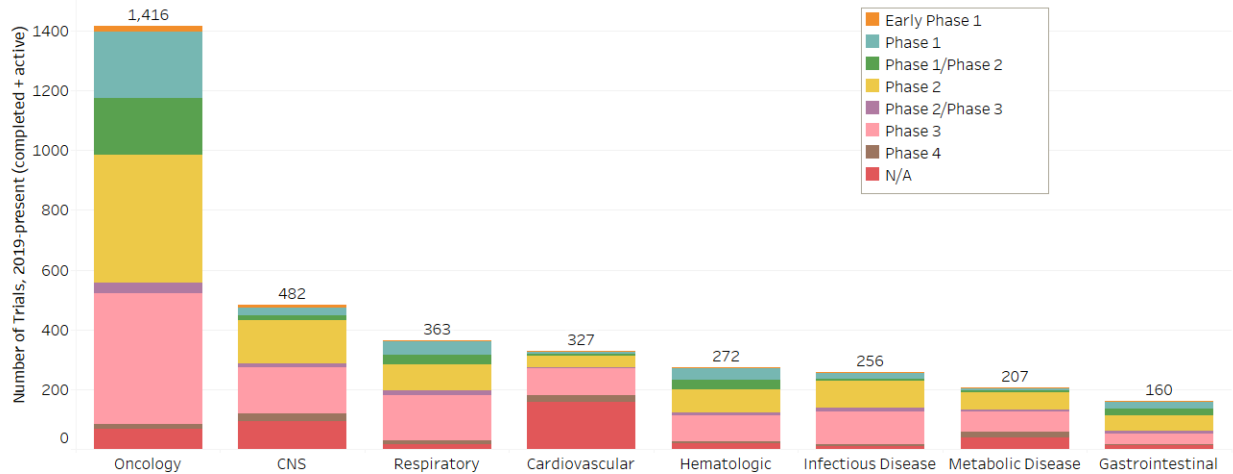

Note: Interventional trials only; excludes terminated, withdrawn, or suspended trials.
Source: TEConomy Partners' analysis of Clinicaltrials.gov data.

As shown in Figure A4, trials activity in the region is also very focused in oncology-related therapeutics, diagnostics, and treatment protocols. Detailed conditions cited with the highest frequency in trials records include conditions such as:

- Breast, prostate, and lung cancer as well as multiple myeloma
- Neurodegenerative disease areas in Alzheimer's and Parkinson's disease
- Studies of treatment regimens and outcomes for Covid-19
- Immunological conditions such as rheumatoid arthritis, asthma, and Crohn's disease

Figure A4: Summary of Interventional Clinical Trials Activity at Sites in Greater Phoenix Region by Major Disease Area, 2019-present

Note: Interventional trials only; excludes terminated, withdrawn, or suspended trials.
Source: TEConomy analysis of Clinicaltrials.gov data.

Market Pull: Details of Analysis of Leading Bioscience Industry Sectors

To set the foundation for understanding the region's industry dynamics, an industry clustering analysis of key economic indicators was developed for the bioscience industry and its major subsectors in Greater Phoenix. Five industry subsectors and their detailed component industries were assessed around key employment-related metrics to understand their performance and relative competitive position. The bioscience industry and its subsectors were defined using the federal NAICS industry classifications used in TEConomy's national studies with the Biotechnology Innovation Organization (BIO) and align with the Arizona bioscience metrics evaluation updates prepared biennially by TEConomy on behalf of the Flinn Foundation. The key metrics include:

- **The relative concentration of detailed industries within the cluster (location quotient or "LQ" analysis),** which represents a measure of which detailed industries are "specialized" within an industry cluster relative to the nation. A regional LQ greater than 1.0 indicates an above-average employment concentration, while an LQ at or above 1.2 indicates a significantly greater level of industry concentration that can be considered a "specialized" industry for the region.

- **Employment changes for detailed industries in the cluster (growth analysis)** – which measures whether an industry cluster is a job generator and is used to view industry performance across business cycles to ensure a thorough understanding of sector and underlying business dynamics.

- **Relative growth of detailed industries in the cluster,** which informs which detailed industries within the industry cluster are gaining or losing competitive share relative to the nation.

Analyses of economic performance leveraged industry employment data from Lightcast, which in turn leverages data from the Quarterly Census of Employment and Wages (QCEW) published by the U.S. Bureau of Labor Statistics (BLS). The QCEW program publishes a quarterly count of employment and wages reported by employers covering more than 95% of U.S. jobs, available at the county, MSA, state and national levels by industry, with Lightcast leveraging this source data to make refinements and adjustments that improve the quality of the reported economic metrics.

TEConomy employed an industry targeting approach combining the metrics described above in a comprehensive characterization of the state of various industry clusters relative to both the regional economy as well as the national. As shown in Table A2, this approach allows the analysis to characterize each bioscience subsector and its detailed component sectors into a profile describing its performance based on its regional economic measures over the 2019 through 2022 period.

Table A2: Summary Industry Assessment Category by Recent Economic Performance

	Regional Economic Measures		
	Location Quotient Above 1.2	Positive Job Growth	Higher Job Growth Compared to National Average
Current Strength	☑	☑	☑
Growing Specialization	☑	☑	
Declining Specialization	☑		
Emerging Strength		☑	☑
Emerging Opportunity		☑	
Declining			

Source: TEConomy Partners, LLC.

As shown below in Figure A5, the Phoenix MSA has experienced significant growth of its non-hospitals bioscience industry cluster in recent years, outpacing job growth rates across the state, the total private sector, and the nation by significant margins. The region's hospitals sector has also grown amidst flatter national growth over the 2019 to 2022 period.

Figure A5: Growth Trends of Greater Phoenix's Bioscience Industry vs. Total Private Sector, 2019-2022
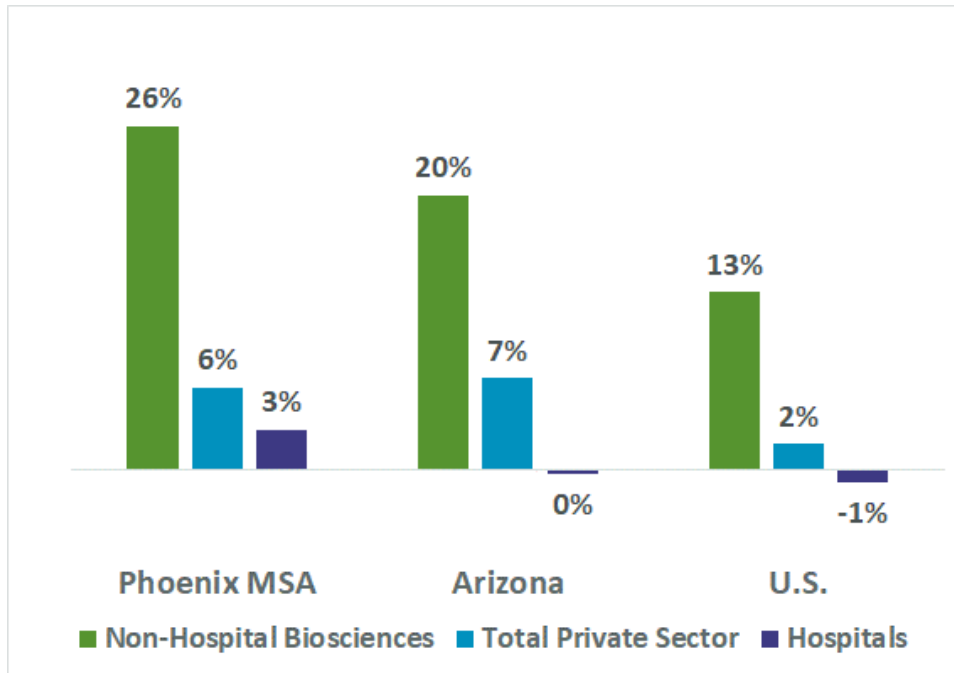
Source: TEConomy Partners' analysis of Lightcast employment data (Datarun 2023.3).

The results of the industry targeting analysis are provided in Table A3. Total jobs in bioscience industry sectors (including hospitals) numbered more than 97,000 in 2022, representing nearly 71% of Arizona's bioscience industry employment. While no major bioscience subsectors were specialized in their relative employment concentration in 2022, the region has a broad base of diversified strengths where employment growth has outpaced the nation, in some cases by significant margins. At the same time, there are several distinct strengths and specializations within the major subsectors that are brought forward in the main report and aligned with the identified growth opportunity areas including medical laboratories, surgical appliances and supplies manufacturing, and in-vitro diagnostics.

Table A3: Economic Performance of Greater Phoenix's Bioscience Clusters, 2019-2022

Industry Subsector	Detailed NAICS Code	Summary Assessment	Phoenix MSA Subsector Performance				AZ Subsector Performance	U.S. Subsector Performance
			2022 Jobs (min. 200)	2022 LQ	Job Change, 2019-2022	MSA Share of AZ Emp, 2022	Job Change, 2019-2022	Job Change, 2019-2022
Total Private Sector			2,010,252	1.00	6.1%	74.9%	6.8%	1.9%
Ag Feedstock & Industrial Biosciences Total		Declining	246	0.23	-7.0%	36.8%	6.1%	1.6%
Bioscience-related Distribution	Drugs and Druggists' Sundries Wholesale	Current Strength	5,099	1.35	7.9%	86.4%	10.3%	7.1%
	Med., Dental, and Hosp. Equip./Supplies Wholesale	Emerging Strength	4,835	1.07	36.5%	81.9%	31.6%	16.5%
	Farm Supplies Wholesale	Emerging Strength	526	0.34	20.2%	50.8%	15.0%	1.1%
Bioscience-Related Distribution Total		Emerging Strength	10,461	1.06	20.2%	81.4%	19.6%	10.2%
Pharmaceuticals	Pharmaceutical Preparation Mfg.	Emerging Opportunity	2,309	0.62	2.8%	97.0%	2.4%	8.0%
	In-Vitro Diagnostic Substance Mfg.	Current Strength	1,085	2.19	106.2%	99.6%	102.3%	14.0%
	Medicinal and Botanical Mfg.	Current Strength	951	1.49	63.9%	94.2%	66.2%	29.3%
	Biological Product (except Diagnostic) Mfg.	Emerging Strength	244	0.36	1106.8%	97.5%	670.2%	20.6%
Pharmaceuticals Total		Emerging Strength	4,590	0.83	36.1%	97.0%	35.1%	12.1%
Medical Devices & Equipment	Surgical and Medical Instrument Mfg.	Emerging Opportunity	2,674	1.16	7.8%	84.6%	14.5%	7.9%
	Surgical Appliance and Supplies Mfg.	Current Strength	2,432	1.40	66.3%	52.9%	12.8%	2.5%
	Electromed. and Electrotherapeutic Apparatus Mfg.	Emerging Strength	660	0.52	26.0%	93.8%	28.2%	8.6%
Medical Devices & Equipment Total		Emerging Strength	5,862	0.90	28.4%	59.9%	11.5%	7.4%
Research, Testing, & Medical Labs	Medical Laboratories	Current Strength	7,116	1.89	23.9%	91.1%	24.2%	15.6%
	Research and Development in the Life Sciences	Emerging Strength	1,936	0.24	41.7%	70.3%	32.6%	25.3%
	Testing Laboratories	Declining	230	0.72	-7.0%	55.4%	3.7%	1.2%
Research, Testing, & Medical Labs Total		Emerging Strength	9,282	0.76	26.2%	84.5%	25.2%	21.4%

Industry Subsector	Detailed NAICS Code	Summary Assessment	Phoenix MSA Subsector Performance				AZ Subsector Performance	U.S. Subsector Performance
			2022 Jobs (min. 200)	2022 LQ	Job Change, 2019-2022	MSA Share of AZ Emp, 2022	Job Change, 2019-2022	Job Change, 2019-2022
Hospitals	General Medical and Surgical Hospitals	Emerging Strength	62,253	0.84	2.1%	67.5%	-1.6%	-1.0%
	Specialty (except Psych and Substance Abuse) Hosp.	Emerging Strength	2,830	0.75	26.8%	69.2%	23.0%	2.6%
	Psychiatric and Substance Abuse Hospitals	Emerging Strength	1,940	1.01	3.8%	63.4%	14.5%	-3.9%
Hospitals Total		**Emerging Strength**	67,024	0.84	3.0%	67.5%	-0.3%	-0.9%
Non-Hospital Biosciences			30,440	0.86	25.5%	78.0%	20.4%	13.2%
Bioscience Industry Total			97,464	0.85	9.1%	70.5%	4.8%	3.1%

Source: TEConomy Partners' analysis of Lightcast employment data (Datarun 2023.3).

Market Pull: Details of Analysis of Regional Bioscience Patent Activities

To understand innovations being advanced by industry in the Greater Phoenix region, TEConomy examined indicators of core technology competencies including patent innovation activity being generated by inventors within the region. Patents are a primary means for inventors to protect their product innovations from being replicated, and as such can be a good proxy for understanding the types of innovation where unique and specialized competencies are being demonstrated in a region. This analysis of patent innovation activity focuses only on patents invented by Greater Phoenix residents in order to best capture the context of innovation generated locally rather than through company headquarters and administrative offices which can include out-of-state inventors. The analysis considers patent applications along with patent awards to provide an assessment of more recent innovation activities since it can take several years for a patent award to be issued from the time of initial application.

Greater Phoenix inventors generated 4,350 U.S. patent records in bioscience-related technology areas from 2019 through the 3rd quarter of 2023, totaling 1,973 patent awards and 2,377 unique patent applications. Totals were adjusted for patent applications that eventually transitioned to awards during this timeframe to avoid double counting.

Another way in which to examine technology themes within patenting activity is to leverage the various technology classes listed on patent records. Examining these technology classes in the context of the combinations of cross-listed technologies that describe the various patent records can provide a more holistic view of the ways in which innovative applications are being advanced. The groupings of technologies are being leveraged together to create new products and services and can be considered as key linkages, with relationships between technologies forming a set of

connections that can be considered together as a network depicting the technology landscape of a set of patents.

When this framework is applied across the set of Greater Phoenix-invented bioscience patent records described above, the resulting technology class network is illustrated in Figure A6. The network nodes, denoted by individual points, indicate an individual patent record, with the size of points indicating the number of forward citations generated by that patent to date. The color of nodes then indicates clusters of highly related technology areas connected by common co-occurring classes listed in patents as determined by network analysis algorithms. Lines connecting nodes indicate connections driven by co-occurring technology classes listed on patent records, with the thickness of lines indicating the strength of connection as determined by the volume of commonly occurring technology classifications.

Figure A6: Technology Landscape of Phoenix Region-Invented Bioscience Patents, 2019-Q3:2023
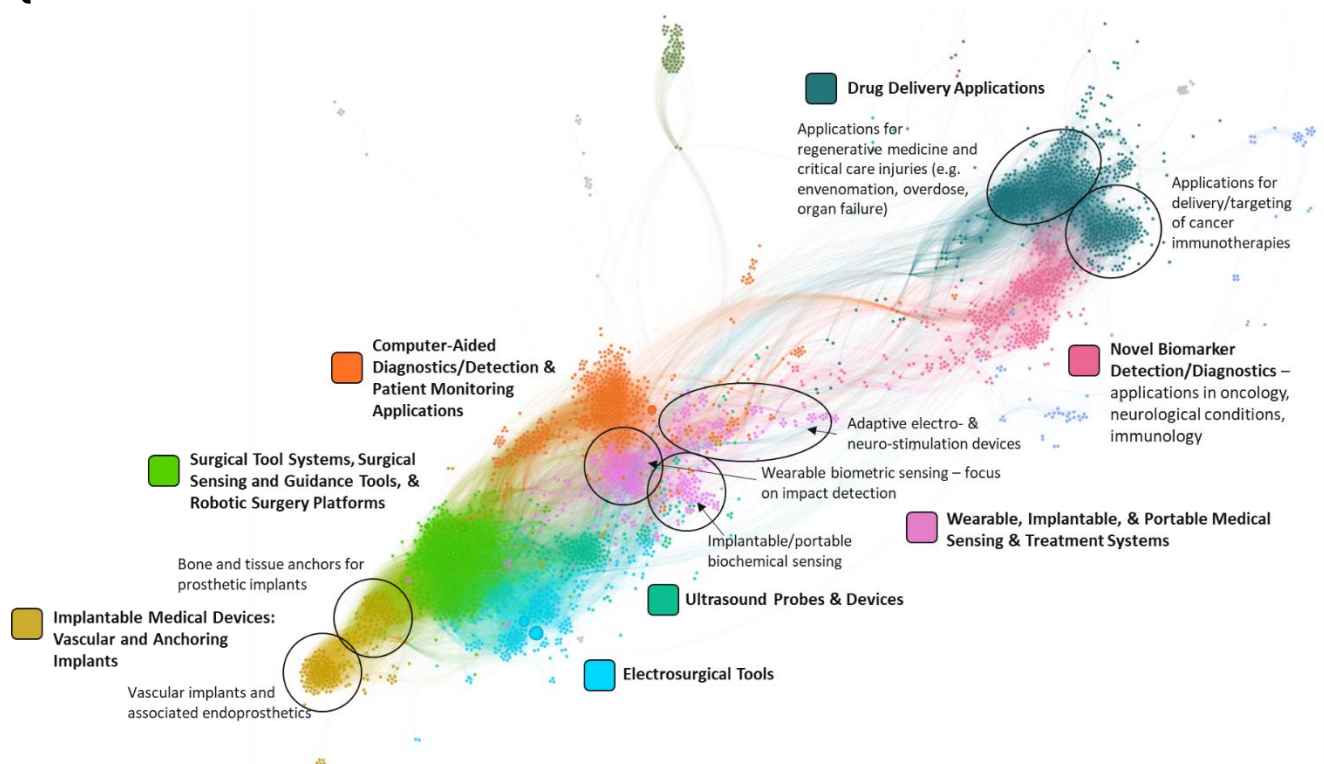
Source: TEConomy Partners' analysis of USPTO data sourced from Derwent Innovation.

As seen on the diagram above, the algorithm identified numerous communities of highly interrelated groupings that make up the major components of the technology landscape, 8 of which were highly relevant to the context of other innovation-led development occurring in the Greater Phoenix region. These clusters included:

- A focus around implantable, surgical, and other biocompatible medical devices, including:
    - Implantable Medical Devices, focused on vascular implants and associated endoprosthetics as well as bone and tissue anchors for prosthetic implants
    - Surgical Tool Systems, Surgical Sensing and Guidance Tools, and Robotic Surgery Platforms
    - Electrosurgical Tools

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- A focus around digital health devices and detection/monitoring technologies, including:
    - Computer-Aided Diagnostics/Detection and Patient Monitoring Applications
    - A variety of Wearable, Implantable, and Portable Medical Systems, including wearable biometric sensors, electro- and neuro-stimulation devices,
    - Ultrasound Probes and Devices
- A focus around drug and diagnostics development, including:
    - Drug delivery applications for regenerative medicine and critical care injuries as well as applications for delivery and targeting of cancer immunotherapies
    - Novel biomarker detection and associated diagnostics with applications in oncology, neurological conditions, and immunology

Market Pull: Details of Analysis of Innovation and Technology Themes Present in Regional Venture Capital Investment Activity

Risk capital investment in bioscience companies is an especially relevant indicator of industry-facing innovation activity where capital is being actively deployed to fund promising products and services among emerging firms. Using the PitchBook venture capital database to examine regional investments, it is possible to identify the companies, industries, and technology "verticals" associated with Greater Phoenix bioscience companies receiving VC funding. Over the 2010 through 2022 period, there was a relatively steady volume of deals annually in regional bioscience companies, though overall levels of funding fluctuated due to the size and stage of investments (Figure A7). The Greater Phoenix region stands out in its higher concentration of MedTech and Healthcare Services investment levels compared to the nation, but has lower levels of investment in traditional biopharmaceutical-related companies.

**Figure A7: Trends in Phoenix Regional Bioscience-Related VC Investments, 2010-2022**
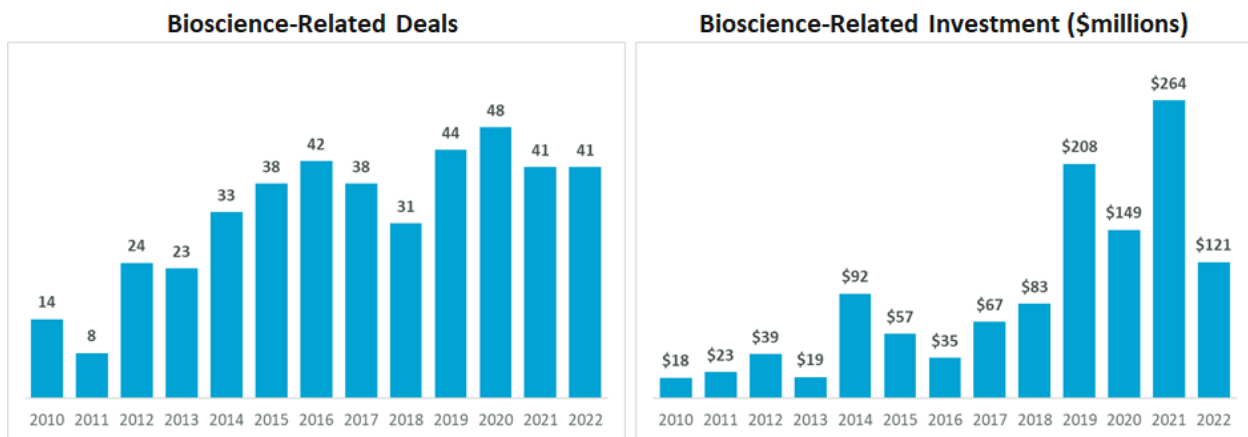
Source: TEConomy Partners' analysis of PitchBook data.

More recently, over the 2019 to 2022 period there were 174 venture capital investment deals in Greater Phoenix bioscience companies totaling $741 million, which equates to 0.98% of total U.S. deals and 0.31% of total U.S. investment funding in the biosciences. TEConomy examined the context of these venture-backed companies advancing bioscience-related products and services

to determine alignment with local universities and entrepreneurial programs which support growth areas.

PitchBook characterizes more than 85 technology verticals that cover a wide variety of areas of innovation activity, allowing for robust examination of the technologies being advanced by companies receiving funding. As shown in Figure A8 below, recent investments have focused on companies developing solutions in Healthtech, Software as a Service (SaaS), and other Digital Health-related applications which complement significant investments in Oncology-related diagnostics and therapeutics.
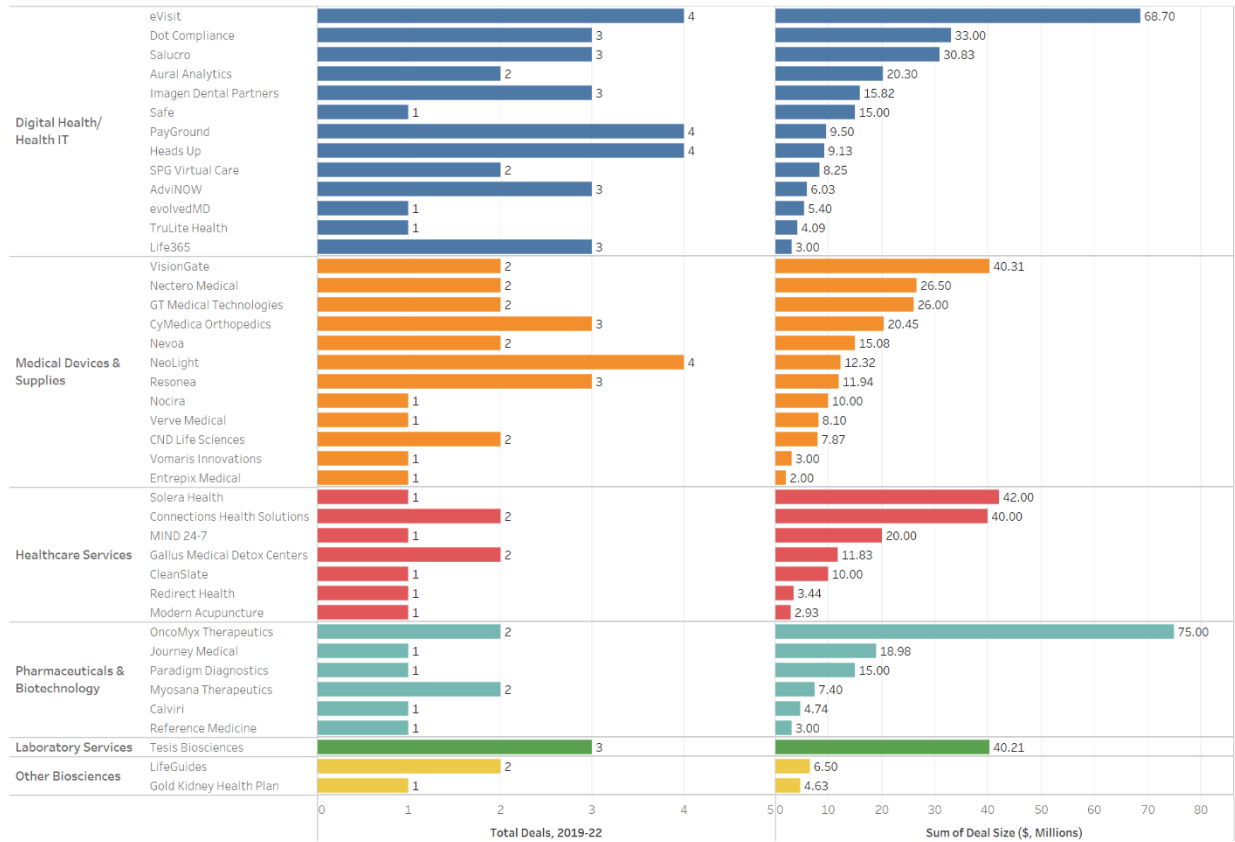
Figure A8: Technology Focus of Recent Phoenix Regional Bioscience-Related VC Investments, 2019-2022
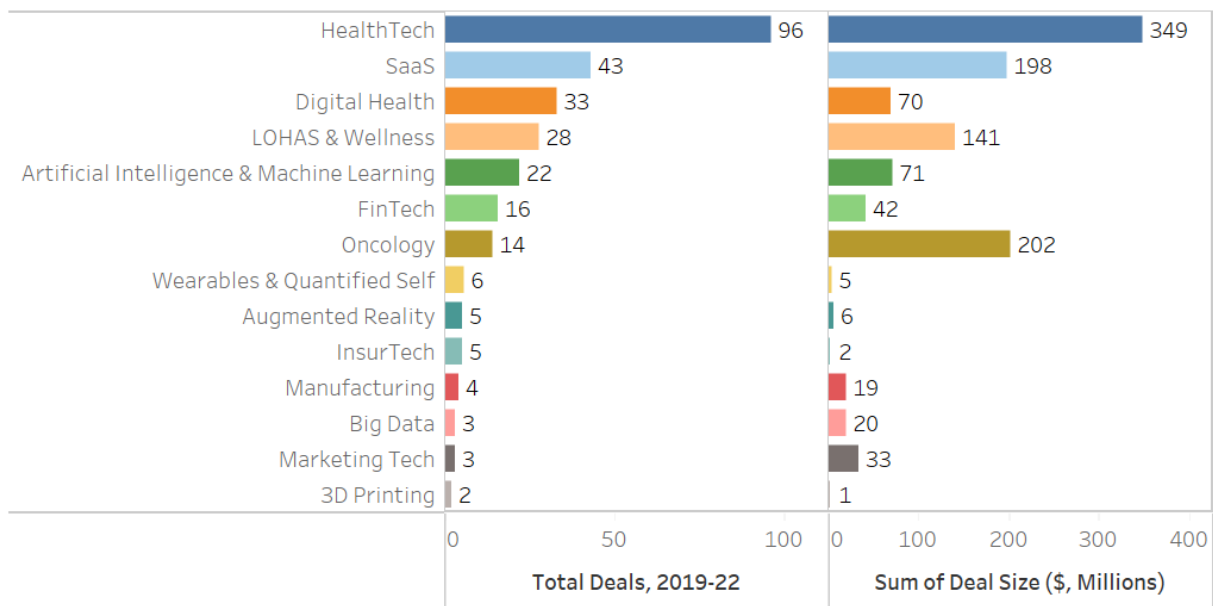
Source: TEConomy Partners' analysis of PitchBook data. Note that companies can be categorized into one or more industry verticals, resulting in sums greater than the stated totals.

Figure A9 below summarizes leading bioscience companies in Greater Phoenix which received significant funding levels of at least $2 million in investment capital and are indicative of key emerging industry activity that supports growth areas.

Figure A9: Regional Bioscience Companies Receiving at Least $2 Million in VC Investment, 2019-2022 (Total Number of Individual VC Deals and Dollars in Millions)

Source: TEConomy Partners' analysis of PitchBook data.