State of Texas

Texas Biotechnology and Life Science Cluster Report

August 2005

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1 – Executive Summary and Recommendations

1.1 – Overview of the Texas Biotechnology and Life Science Cluster Assessment

The Texas Biotechnology and Life Science Cluster is part of an intensive effort to bolster and exploit Texas' competitive advantage in six technology areas – each identified as key to the state's future economic growth. This report summarizes an in-depth statewide assessment that involved more than 250 people from every segment of the industry and every region in the state. We use this report to discuss the importance of biotechnology and life sciences to Texas' economic future, Texas' position – the "Right to Play" – in these industries and how Texas can succeed in building strong economic growth and create new higher wage jobs – the "Right to Win". Further details are provided in the Appendices of this document.

Biotechnology and Life Science Cluster — Opportunity for Job Creation

The Texas Biotechnology and Life Science Cluster is robust and well positioned for exceptionally strong economic expansion. Including disciplines, markets, products and services that draw primarily from biology and the life sciences, it is a broad industry. It ranges from pharmaceuticals and medical devices to agriculture, oil spill and toxic waste remediation, marine and fisheries, and biohazard sensors to renewable energy sources.[1] All of these fields represent dynamic, growing industries that will significantly impact economies across the globe and benefit lives not only in Texas, but on every continent.

The biotechnology industry is a vast field with much potential. According to the U.S. Department of Labor Employment and Training Administration website: Industry revenues more than quadrupled from $8 billion in 1992 to $33.6 billion in 2002. (Ernst & Young) The life, physical, and social science occupations group is one of the top five occupational groups that has the highest projected percentage increase in employment between 2002 and 2012. Employment in the life sciences is expected to grow by 18%, led by a 19% increase in biological scientists. Biological technicians are also expected to increase by 19%. (U.S. Bureau of Labor Statistics) Employment in pharmaceutical and medicine manufacturing is projected to increase by 23% between 2002 and 2012 (U.S. Bureau of Labor Statistics).

Sound reasoning and facts support the drive for Texas to become a dominant player in the biotechnology and life sciences industries. Not only does Texas boast of the world's largest medical center and the world's capital of human space flight, Texas also is home to outstanding technology, agricultural colleges and medical schools, engineers and scientists.

[1] Though direct patient health care delivery is one of Texas' major and most important industries, it is not included for the purposes of this industry cluster grouping.

Nationally, Texas ranked in the top 20 states for producing patents in medical equipment and medical electronics, pharmaceuticals and biotechnology in the past seven years. Over the past five years, the biotechnology industry in Texas has experienced growth of 149% compared to the previous five years. Texas has doubled its funding from the National Science Foundation over the past ten years. Since 1993, Texas has received $6.4 billion for research and development within the life science and biotechnology fields, 10.2% of which was used for infrastructure. Add to that, between 2000 and 2004, $360.8 million of private sector funded research and development has occurred in Texas. Texas is primed for expansion and global competition within biotechnology and life sciences.

1.2 – Recommendations

Life science companies and institutions in Texas need to be able to quickly adapt to change. This agility will enable them to rapidly leverage present and future opportunities to sustain research, to bring new products to market readily, and to leap ahead of competitors. Texas must finalize and then quickly execute a strategic plan for the biotechnology and life science industry that will translate these recommendations into results. Emphasis must be placed on implementation – regional champions should come together to advocate an action-oriented statewide plan leading to long-term economic and societal benefits for Texas.

The issues below are a distillation of the recommendations of the Texas Biotechnology and Life Science Cluster Initiative assessment. These recommendations aim to identify significant and primary statewide issues that may either hinder or enhance a vigorous and growing biotechnology and life science industry in Texas and suggest actions that promote robust growth and job creation.

Each issue identified here is significant in that if addressed appropriately and adequately by itself, it can create a sizable boost in Texas' capacity in the biotechnology and life science cluster. Each issue is primary in that individually they are foundation stones on which the biotechnology and life science cluster development must necessarily stand. Each issue presented here is also "actionable" by state government — that is, steps taken by state government either through legislation, appropriation, advocacy or executive action can improve circumstances. Together these recommendations represent real, substantive goals to boost the biotechnology and life science cluster in Texas and our position nationally and internationally in these industries.

1. **Designate a Regional Center of Innovation and Commercialization (RCIC) for the Biotechnology and Life Science Cluster.**
   Commercializing biotechnology requires Texas to build an environment to sustain it. One clear avenue to acknowledge the unique needs of this cluster opportunity is through the Texas Emerging Technology Fund (ETF) and the Regional Centers of Innovation and Commercialization (RCIC) that will be developed and designated.

   ETF will provide some of the funds and a system to identify and develop competitive enterprises that will help keep Texas in the global competition. The RCICs can connect the private sector and institutions of higher education to build on successes. From research and development to incubators for start-ups, to existing companies commercializing their projects and workforce training for employees – the centers will generate opportunities for many.

Texas needs an RCIC designated for the biotechnology and life sciences cluster to ensure it can compete and win in the global marketplace.

2. **Increase the identification of federal and private technology development grants for the Biotechnology Cluster and ensure that Texas gets its fair share of grant funds.**
   The ETF component to match Biotechnology research grants awarded by federal or private sponsors will help Texas researchers better compete for out-of-state dollars because sponsors know that their contributions will have double or more the impact.

3. **Further develop Texas public universities as world leaders in biotechnology and life science research.**
   ETF earmarked funds for biotechnology and life sciences will help attract more renowned research teams to lead company creation, expansion and relocation from the Texas-developed research and increase commercialization coming from Texas universities.

4. **Expand and support biotechnology curriculum and training programs in high schools and two and four-year colleges.**
   This includes not only specific curriculum but also the equipment and teachers, internships and externships needed for such education and training.

5. **Increase awareness of science literacy and training for students, teachers and the public particularly for grades K-12.**
   Problems of attracting and keeping students in science fields must be addressed in elementary and secondary schools. Primary science education must build upon students' innate curiosity and interest in science, engineering, and technology fields and foster the ability to digest and use information, not just demonstrate their ability to re-iterate "facts". It is during the elementary grades that students begin to develop the basic skills and grounding that will allow them to become the technicians, engineers and scientists of tomorrow, as well as the leaders and communities who oversee and vote upon the funding and use of technological advances.

6. **Nurture the Biotechnology and Life Science Cluster as an identified target industry for the state, this cluster offers significant and quantifiable economic benefits to the state.**
   The Biotechnology Cluster Team is committed to providing the insight, direction and experience to identify and grow this sector for Texas. We welcome the opportunity to provide the leadership and collaboration necessary to accomplish this goal for the state.

7. **Promote the Biotechnology Cluster with an ongoing state-run communications campaign both outside and within Texas to recognize the value of this cluster to the Texas economy.**
   This affects Texas at many levels: attracting and keeping talented researchers and research dollars; leveraging intellectual property, communicating and preparing students for career opportunities in biotechnology and life sciences; building vibrant networks of researchers, entrepreneurs and their stakeholders and growing the cluster itself.

1.3 – The Texas' Biotechnology and Life Science Team

The Texas' Biotechnology and Life Science Cluster team was convened in May 2004 to guide this comprehensive, competitive assessment of the industry cluster and to recommend the allocation of state resources. The team represents a broad cross-section of public and private sector stakeholders from around the state and includes individuals who represent the core functions, products and technologies within the cluster.

The team will continue to monitor the competitiveness of the biotechnology cluster and will recommend ways to coordinate activities within the state to efficiently react to opportunities and threats affecting the cluster. The team will also work to increase the capacity for innovation, thereby accelerating the growth of the cluster. Through their contribution to implementation along with longer-range planning, the team will assist in the retention, expansion and recruitment efforts of the biotechnology and life science cluster.

The Biotechnology and Life Science Cluster team acknowledges the work, report and recommendations made by the Governor's Council on Science and Biotechnology Development convened in 2002. Several members have served on both initiatives. Many of the recommendations from the Governor's Council have received attention and been resolved over the past two years, while others continue to require attention and served as the basis for discussion within the cluster team and throughout this statewide assessment process. A summary of the findings of the Governor's Council on Science and Biotechnology including the recommendations is included in Appendix F.

2 – Summary of Findings

The "Right to Play" Biotechnology and Life Science in Texas are Robust High Growth Industries

This assessment was driven by an extensive analysis of the Texas biotechnology and life science industry. This process included research of both a quantitative and qualitative nature, including direct input from statewide representatives on the Biotechnology and Life Science Cluster team, an electronic survey, interviews, and regional forums with key members of the Texas biotechnology and life science community. More than 250 Texans helped shape the following general findings and subsequent recommendations found throughout the report.

Initial Findings from Quantitative and Qualitative Sources		
Issue	**Description**	**Example**
Value Chain	While the number of commercial entities continues to grow, the recruitment of appropriate value chain elements has not matched the completion of a cluster dynamic for critical mass.	State and regional economic development plans lack an understanding of the current and emerging vendor-supplier chains for industry growth.
Resource Application	Analyzing the current discovery-development-delivery process in the Life Science Cluster has identified a few shortfalls in Texas' approach to cluster development.	There is a lack of appropriate means for prioritizing how resources are currently engaged to address opportunities and threats in academia, industry and the public sector.
New Approaches to Capital Formation	New approaches to capital formation are necessary particularly for gap funding for start-up/enterprise development and to increase the success and growth of biotechnology firms.	Examples of new approaches include leveraging economic incentives, resource allocation, unlocking dollars in pension and other funds for increased investment in the life science commercialization arena.
Human Capital	Opportunities abound for experienced senior management to lead start up biotech enterprises to ensure growth and expansion. There is a poor provision of interlocking skill and career pathways for students and adults to meet the future demand in a responsive public workforce delivery system.	Talented biotechnology and life science managers gain valuable experience on one of the coasts and chose to relocate or come home to Texas. There is a lack of articulation agreements between post-secondary institutions. Linkages for career development among degree-providers are ill-defined.
Federal Funding	Texas has attracted over $25 billion in federal funds – some $7 billion in life science alone – yet competitor states have created unique measures to ensure they never leave any dollars on the table in Washington.	Texas needs to agree upon an organized federal funding and overall resources development strategy similar to activities in California, Massachusetts, and Georgia.
Infrastructure	Although the nine million square feet of research and delivery space is competitive, Texas' lacks specific infrastructure in the next stages of cluster activities to attract world class talent and dollars.	Flexible "Wet Lab" space, commercialization space proximate to research centers of excellence; manufacturing and bioprocessing facilities are needed.
Leveraging Strengths in Clinical Trials	Texas has long been a national leader in conducting clinical trials, especially in the cancer sector. With infrastructure, facilities, investigators, thought leaders, and a genetically diverse large population, Texas is likely to maintain that leadership.	Texas can use this leadership position to build the relationships necessary to accelerate the growth of the biotechnology cluster and job development through a more focused opportunity identification process and a global network.
Increased Connectivity	A new tool should be created to address the gap in knowledge-sharing among researchers, principal investigators, technologists, innovators, and investors and across regions in the State.	There is no current tool or mechanism to leverage region-to-region scientific, technological, nor economic advantages.
Branding and Positioning	Branding and positioning is needed to communicate to students, workers, legislators, policy-makers, and economic developers, as well as external interests and global markets.	Texas needs to increase the awareness of the life science industry as a major driver of economic and societal benefits, while promoting its current and emerging advantages, assets and people.

3 – Cluster Definition

The NAICS (North American Industry Classification System) measures business activities based on key employment and wages related to traditional and emerging sectors. These identification codes assist in measuring performance at the state and county levels on a quarterly basis and provide comparisons across several years. Thus, by combining the appropriate mix of NAICS codes, one can model the clustering of economic and business results from the interplay of collaborating firms, institutions, and organizations. For the biotechnology and life science cluster, the following NAICS codes were selected:

Table A NAICS Codes Used for Biotechnology and Life Science Cluster Assessment [i]

NAICS	Industry Name	2003 TX Employment
3254	Pharmaceutical and Medicine Manufacturing	8,997
3345	Electronic Instrument Manufacturing	19,533
3391	Medical and Dental Equipment Manufacturing	13,474
5413	Architectural, Engineering, Testing Lab Services	110,303
5416	Management & Technical Consulting Services	47,656
5417	Scientific Research and Development Services	17,458
5419	Market Research and Other Professional Services	32,546
6215	Medical, Diagnostic, Laboratories and Imaging Centers	13,042

These selected sectors assist in identifying employment and wage patterns at a macro-level, and often include a number of industries and cross-cutting interests. When defining a cluster, in addition to primary cluster activities such as biotechnology, life science, plant-animal research and development, one must also include secondary cluster activities such as medical devices, professional services, testing and laboratories. Other sectors which have an impact on biotechnology and the life sciences that are not represented in this count, but are considered relative to the growth of a competitive cluster, are legal services, accounting services, investment services, certain elements of academic institutions, and chemical preparation and manufacturing. To strengthen the definition of the cluster, Table B illustrates the link between overall employment and the occupations driving the development of the biotechnology and life science cluster.

As of 2004, over 75,000 individuals are employed in the biotechnology and life science cluster throughout Texas, with an average wage ($48,000) nearly double the state average (approximately $25,000). Some occupations are three or four times the state average, signaling that the industry attracts high-wage, high-value positions in addition to providing opportunities for high-school, community and technical school graduates with competitive salaries. (Table B)[ii]

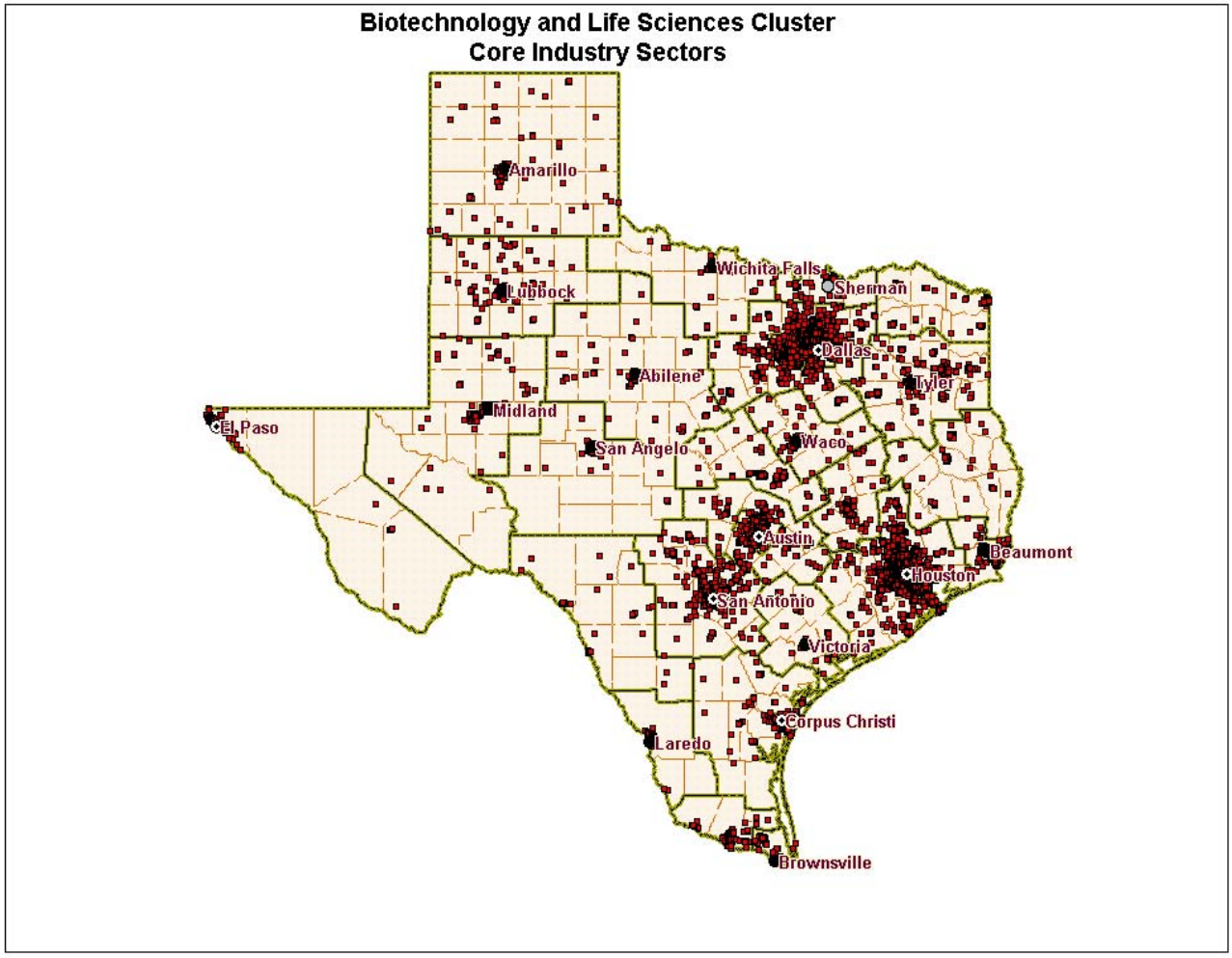
Table B

Conservative Estimate of 2004 Employment and Average Wages by Select Life Science Sub-Sector Occupations		
Life Science Sub-Sector	**2004 Employment**	**2004 Average Wages**
Biomedical Engineers	100	$ 48,119
Biochem/Biophysics	547	$ 63,768
Microbiologists	1384	$ 46,138
Medical Scientists	2426	$ 52,063
Life Scientists	336	$ 48,486
Environmental Scientists	5150	$ 46,444
Epidemiologists	267	$ 43,378
Biotech Teachers, Post Sec	3976	$ 61,935
Pharma/Medical Manufacturers	9070	$ 34,943
Pharma/Medical Researchers	N/A	$ 64,435
Natural Science Managers	2466	$ 81,092
Biological Technicians	2869	$ 31,360
Life/Physical/Social Science Techs	6971	$ 24,696
Veterinarians	2403	$ 66,518
Health Diagnostic-Testing	7390	$ 65,965
Medical/Clinical Lab Technos	8497	$ 42,314
Medical/Clinical Lab Technician	9449	$ 23,097
Medical Record and Health IT	9263	$ 23,954
Mathematician related to Health	51	$ 48,000
Envi-Sci and Protection Techs	2884	$ 36,633
Totals Employ & Average Wage	**75499**	**$ 47,666**
Texas Total Employ/Wages	**Not Applicable**	**$ 25,931**

Texas possesses a growing number of companies and institutions that increase the likelihood that the state can emerge as a global competitor in the biotechnology and life science industry. While the biotechnology and life sciences industry cluster does not yet generate the number of jobs of more traditional industries, current trends indicate that this cluster will grow rapidly.

The Biotechnology and Life Science Cluster assessment focused on regions in Texas with the greatest concentration of cluster employment. This map shows the Biotechnology Cluster in Texas with each dot representing an employer with 5 or more employees that operates in the core biotechnology businesses. Core business is defined as those employers who provide services or applied research or manufacture goods in the biotechnology and life sciences industry.

Figure 1 Core Employment in the Biotechnology Cluster[iii]



Workforce Support

Within the sectors of the Biotechnology and Life Science Cluster are the positions and job characteristics that comprise one of the fastest-growing employment opportunities for Texans. Although Table B (on page 10) provides only a sample of the fifty to sixty different types of jobs within the cluster, conservative estimates of the overall employment picture suggest that a broad range of Texans will benefit from the increased vibrancy of the cluster.

Of further importance is the background education required to obtain a position in these core and supportive positions. Not every job requires a four-year college degree, much less a graduate or post-doctoral certification. Ranging from high school and community/technical colleges to graduate programs, the opportunities for increased job growth will demand skills and competencies from every region in the state.

As well, the cluster offers *transformative* job opportunities – positions that might be shrinking in traditional sectors that could be transitioned into the biotechnology and life sciences sectors. For instance, an individual with a background in chemical preparation from the energy sector could find employment assisting in the formation of new compounds for drug manufacturing; individuals with skills in information technology and engineering have significant opportunities in medical devices and healthcare delivery.

Research, Education and Academic Capacity

This technology-intensive cluster requires a wide range of skilled workers – from community college graduates to post-doctorates and everything in between.

- Texas' academic research institutions and corresponding health science centers – not to mention community and technical colleges – are locations of knowledge-creation in a variety of scientific and technical fields. There are at least 55 specific biotechnology and life sciences program concentrations at Texas academic institutions, according to the Texas Higher Education Coordinating Board.

- In the past three years, curricula and courses have been launched in emerging areas such as biomedical engineering, bioinformatics, genetics and proteomics, bio-manufacturing, nanotechnology and materials related to medical devices. These new courses have spurred additional certification programs at the post-doctorate graduate levels as well as for individuals already in the workforce at more senior levels.

Laboratories and Physical Infrastructure Resources

For over fifty years, regions throughout the state have sponsored, designed and constructed some nine million square feet of academic-based healthcare delivery and life science research facilities. A majority of the square footage is academic research space connected to or built in conjunction with hospitals, clinics, and outpatient services. Over 7 million square feet of research laboratory space have been identified in key scientific areas on Texas campuses. The Biotechnology and Life Science Cluster is heavily dependent upon academic institutions to discover and often co-develop the new products and services that result in economic and business growth. Estimates for the end of 2004 and early 2005 suggest that an additional two million square feet of research laboratory space will either be completed shortly or is planned to be built in the near-term.

As a result of this significant investment in brick-and-mortar infrastructure – which came largely from public sector and philanthropic sources – Texas is well positioned to advance its life science research by devoting its future resources to unique programs, special facilities and equipment, and the increased commercialization of new products and services.

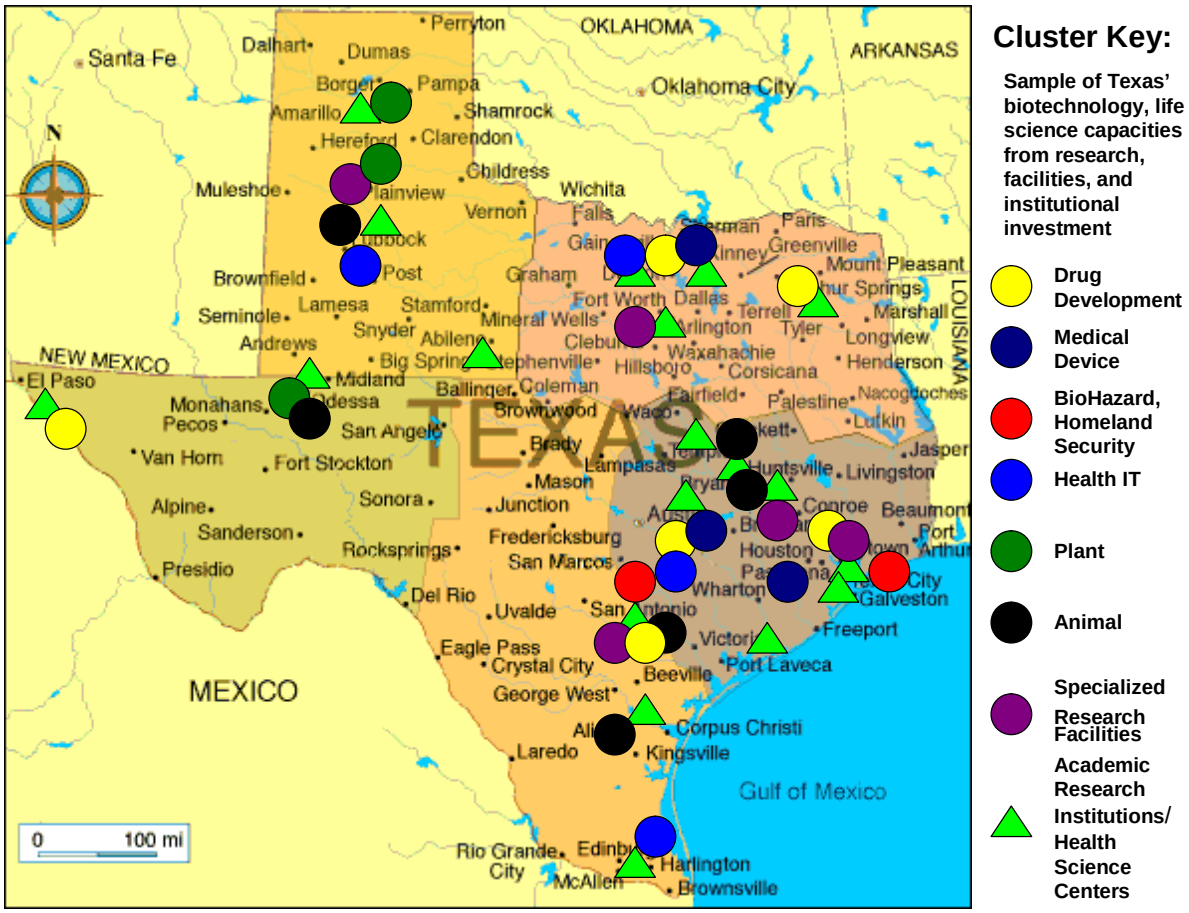
4 – Competitive Landscape

Over the past twenty years – and especially in the last twelve – Texas has become home to startups as well as operations from global pharmaceutical, biotechnology and other related life science corporations. Many of these facilities and plants are located within proximity of the academic campuses.

In this emerging industry cluster, the typical Texas biotechnology company is small in terms of employment, although there are also a handful of very large firms that operate at the international level. According to the U.S. Economic Census, in 2002 there were 791 companies manufacturing biotechnology-related products in Texas, employing 25,526 people, for an average size of about 33 employees.[iv]

This map shows some of the breadth of Texas capacity – it is not intended to provide a complete picture. The key message is that Texas is in a position to leverage several facets of this cluster industry and identify targets of opportunity in order to focus resources most effectively.

Figure 2 Texas Biotechnology and Life Sciences Industries [v]



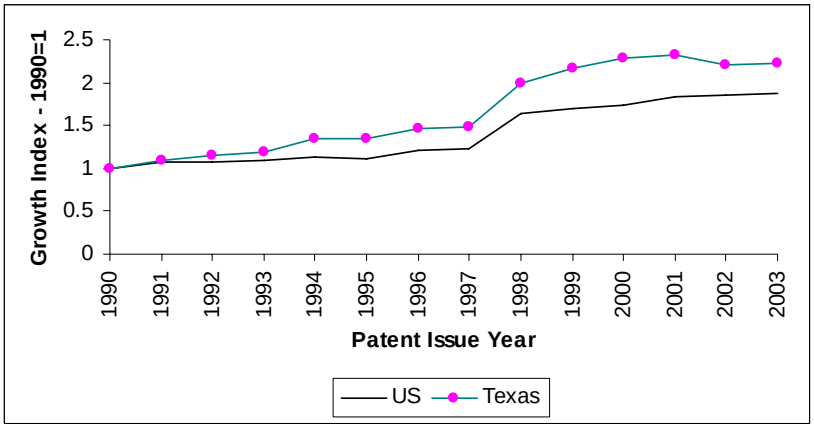
Compared to other states, investment and market capitalization of the biotechnology industry in Texas has not been quite as robust. Table C.

Table C Investment and Market Capitalization

Biotechnology Activity in Selected States, 2003 [vii]								
State	**# Public Firms**	**Market Capitalization**		**Revenue In Dollars (Mil.)**	**R&D**	**Net Loss (Income)**	**Long & Short-term Investments**	**Total Assets**
		In Dollars (Mil.)	**Percentage Change from 2002**	**Dollars (Mil.)**	**Dollars (Mil.)**	**Dollars (Mil.)**	**Dollars (Mil.)**	**Dollars (Mil.)**
Texas	12	$3,076	-8%	$166	$218	$205	$681	$992
California								
San Francisco	59	$95,906	99%	$10,327	$4,065	$678	$8,649	$25,758
San Diego	27	$12,514	(4%)	$1,617	$1,024	$689	$2,888	$6,242
LA/Orange C.	14	$83,900	26%	$10,148	$1,944	($2,308)	$6,361	$29,549
New York	15	$7,281	98%	$446	$567	$583	$1,347	$2,346
Pennsylvania/ Delaware	11	$4,905	20%	$831	$517	$293	$1,684	$3,136
New Jersey	27	$10,355	75%	$1,181	$481	$243	$1,883	$3,816
N. Carolina	12	$4,861	30%	$1,232	$254	$78	$497	$1,797

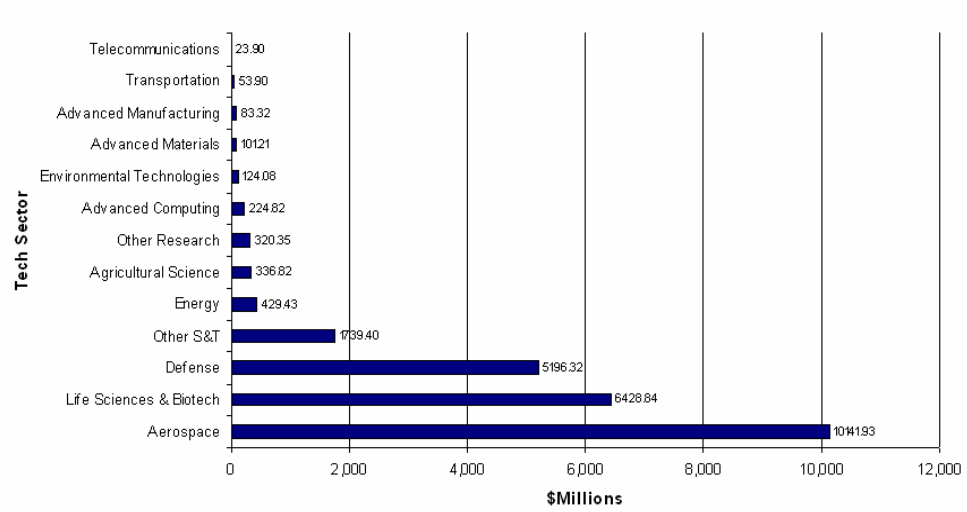
Intellectual Property growth in patenting in Texas generally outpaced the U.S. average from 1990 to 2003.

Figure 3 Intellectual Property Growth in Patenting in Texas[viii]



Texas has received increasing amounts of unclassified research and development federal funding over the past 7 years with a higher percentage going to the life sciences and biotechnology second only to aerospace. Figure 4.

Figure 4 Unclassified Federal R&D Funding to Texas by Tech Sector, 1993 – 2003[ix]



As Table D shows, Texas has consistently received significant amounts of federal dollars as compared to other states.

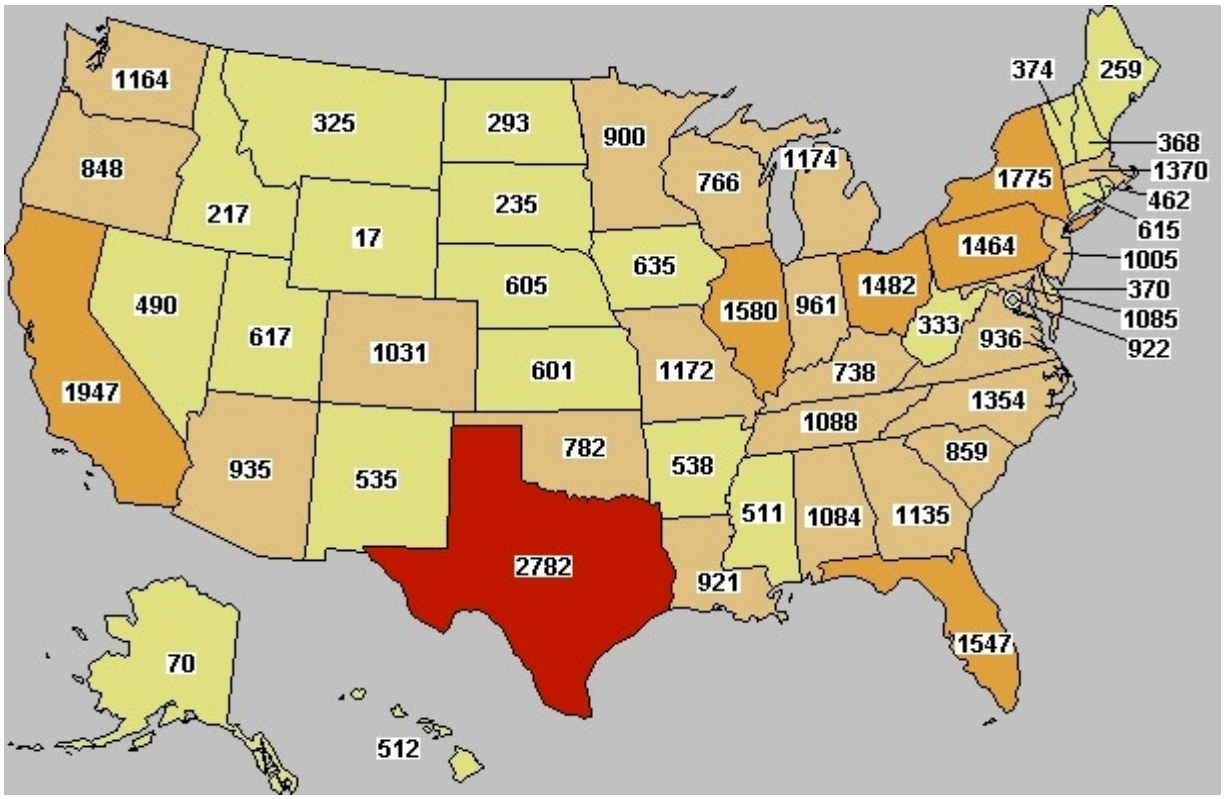
Table D

Top States by Federal R&D Funding to Universities and Colleges, 2003 (millions of $) [x]			
#	**State**	**2003 Funding**	**% of Total***
1	California	2,726	12.8%
2	New York	1,670	7.8%
3	Pennsylvania	1,327	6.2%
4	Texas	1,833	6.0%
5	Maryland	1,303	5.8%
6	Massachusetts	1,196	5.6%
7	North Carolina	858	4.0%
8	Illinois	818	3.8%
9	Michigan	659	3.1%
10	Ohio	588	2.8%
*Total Federal R&D Funding for all States = **$21,352 million.**			

Clinical Trials

Texas is a leader in the national clinical trial activities for global and domestic pharmaceutical, biotechnology and medical device firms. This depth of attracting and managing trials indicates the state's capabilities in scientific research.

Figure 5 Distribution of Active Clinical Trials in the U.S., 2005[xi]



The state's leadership position in clinical trials needs to be leveraged to expand relationships with industry conducting the trials, capture more of the intellectual property and facilitate commercialization that will accelerate the growth of the biotechnology cluster in Texas.

Investment

Trends in venture capital investments in Texas mirror those of the nation (Figure 6)[xii], but there have been disparities in venture capital trends within the life sciences (Figure 7).[xiii]

Figure 6: Growth of VC Investments, US & TX, 1995 - 2003

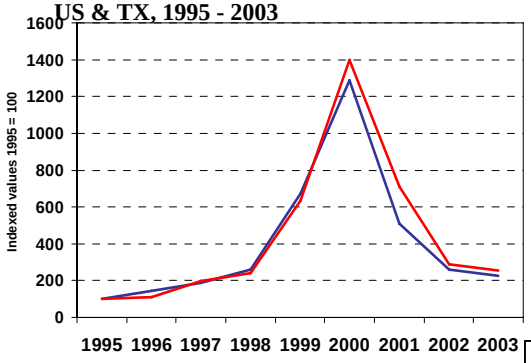
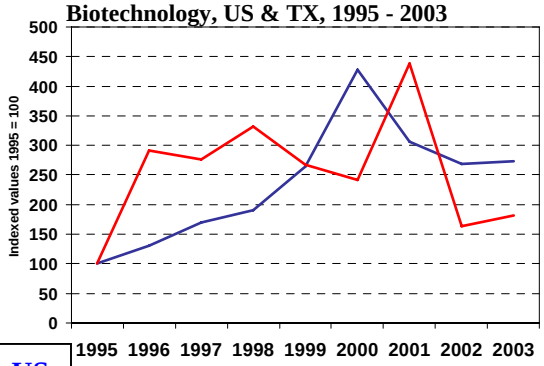


Figure 7: Growth of VC Investments in Biotechnology, US & TX, 1995 - 2003

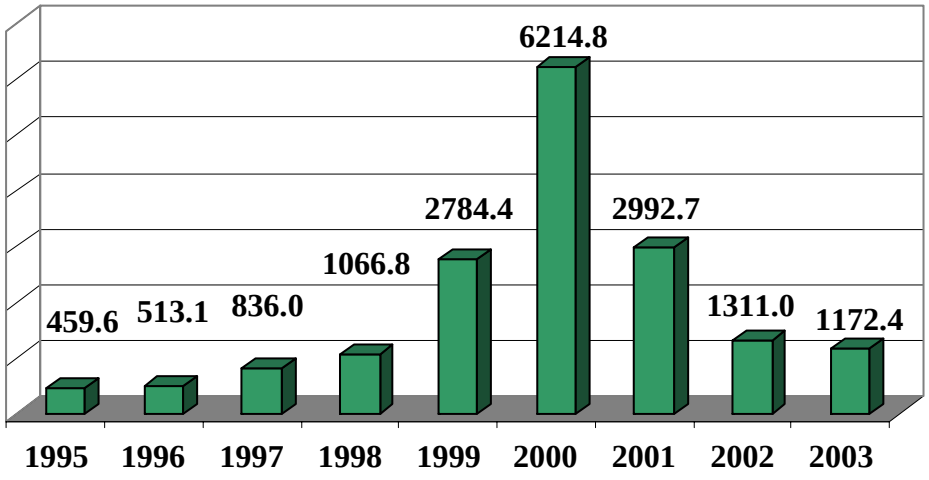


Blue = US
Red = TX

As it did nationwide, venture capital investment in Texas dropped off significantly in the wake of the economic slowdown that began in 2000. Total venture capital investment in Texas has yet to bounce back significantly – it dropped from a high of $6.2 billion in 2000 to $1.2 billion in 2003 (Figure 8).[xiv]

Figure 8

Total Venture Capital Investment in the State of Texas, 1995 - 2003 (millions of $)

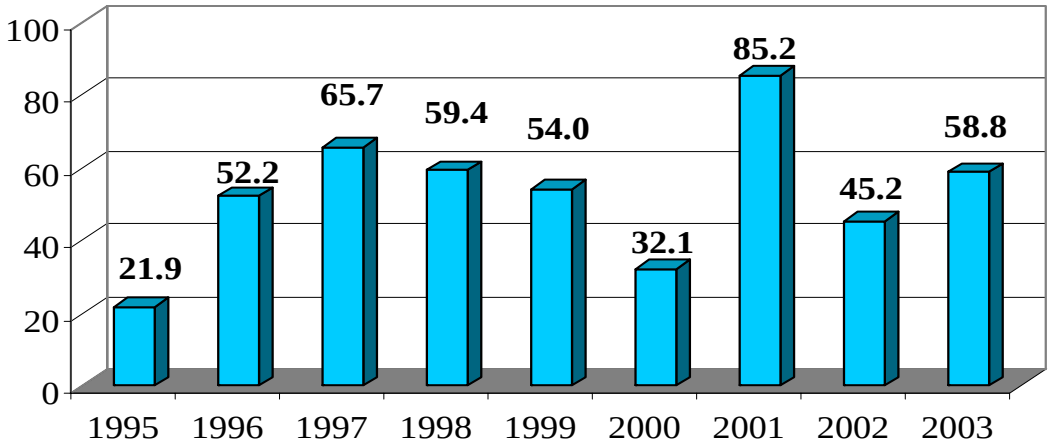


Venture capital investment in the biotechnology sector has remained steadier – it did not experience the same precipitous drop-off as other sectors, and there is less evidence of a clear

trend (Figure 8). Venture capital investment in biotechnology totaled $58.8 million in 2003, up from an eight-year low of $32.1 million in 2000 (Figure 9).[xv]

Figure 9

Venture Capital Investment in Biotechnology in the State of Texas, 1995 - 2003 (millions of $)

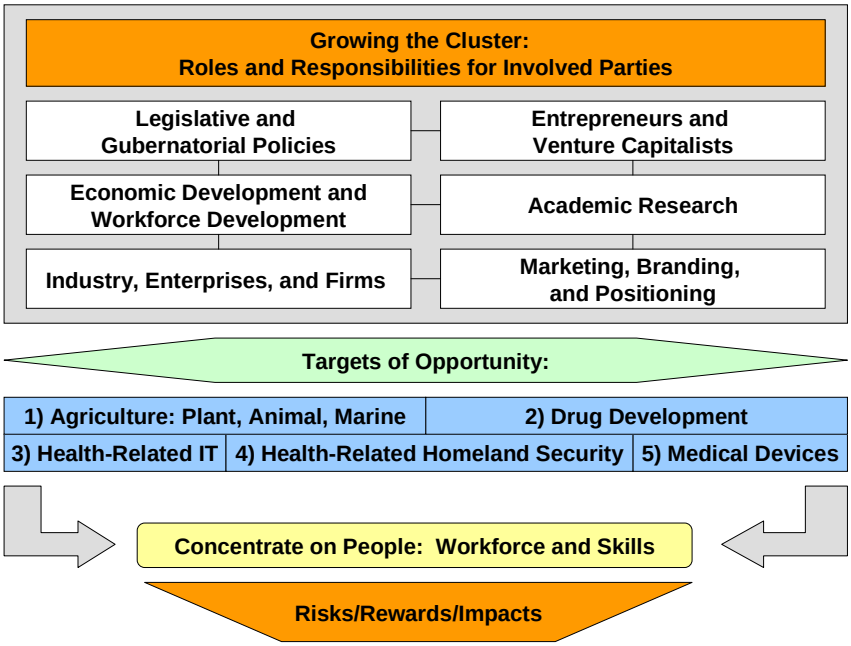


Realizing Economic Growth Potential and Job Creation in the Biotechnology and Life Sciences Industries Cluster

To succeed, development and growth of an industry cluster requires:

- a critical mass of intellectual property and talent in the disciplines supporting the advancement of the industries;
- a workforce trained to manage, manufacture and deliver the products and services;
- the physical infrastructure to support product development, manufacture and deliver;
- timely infusion of "smart" –capital money – especially early stage investments,
- start-up and mid-size businesses at important phases of growth; and above all,
- the awareness, advocacy and expressed will of investors, the public and government to support the Biotechnology Cluster's expansion.

Figure 10. Requirements for Growing the Biotechnology and Life Sciences Cluster.[xvi]



Texas has the resources and capacity to move to the next level of growth by focusing resources and completing this strategic initiative through implementation.

5 – Assessment Methodology and Approach

In order to engage a broad set of stakeholders and to capture their ideas regarding creating a strategic plan for the Biotechnology Cluster, both high-level and grassroots activities were used, including:

- an electronic online survey of state and regional innovation mindset
- interviews with sixty key stakeholders
- five regional forums
- ongoing legislative and policy discussion with the Cluster Team

The intent of this qualitative approach was to gain valuable insights, commentary and guidance from over two hundred fifty practitioners, industry leaders and vendor-suppliers supporting the growth of the cluster.

Through this approach, a series of recommendations were created for the Cluster assessment and appendices of related documentation.

6 – Qualitative Data

6.1 – Qualitative Data - Survey of the State and Regional Mindset

An online survey was conducted to gauge the state and regional mindset in Texas. Of the 2,000 invitees, 440 responded (a 22% response rate comment). Detailed survey results are provided in Appendix G. Key findings included:

- 58% of respondents participate in or were aware of activities to promote and grow scientific, technological and economic outcomes in the life sciences.
- Only 33% of respondents were satisfied with the current pool of entrepreneurial managers in the life sciences.
- 52% of respondents were dissatisfied with capital formation strategies in Texas.
- Only 41% of respondents were satisfied with Texas' ability to attract scientists and engineers, while only 37% were satisfied with prospects to retain them in the future.
- 55% of respondents were dissatisfied with K-12 math and science offerings, and an equal percentage were concerned about the disconnect between such skills and the overall workforce strategies of the state.
- A majority of respondents indicated a desire for an online portal or other similar tool to connect common interests; 51% want to be connected to all things in capital and resource formation (VCs, angels, federal and state, philanthropic).

6.2 – Qualitative Data - Stakeholder Interview and Regional Forum Perspective

Sixty in-depth interviews were conducted, as well as 250 people participated in two-hour regional forums in the Dallas/Fort Worth Metroplex, Austin, San Antonio, Lubbock and Greater Houston/Gulf Coast areas. While a variety of viewpoints were expressed, it was clear from the interviews and forums that a broad consensus exists for near- and long-term sustainable action. The general recommendations focused on a few key issues:

- Improving and streamlining the commercialization process through centers of entrepreneurial and innovation-focused counsel, guidance and collaboration.
- Increasing regional cooperation and state coordination (including identifying and focusing on comparative advantages among regions and redressing regional disparities).
- Increasing and improving workforce development at all levels, especially in high schools and community colleges (leveraged through industry/academia partnerships).
- Increasing funding for research collaborations, leveraging with federal grants, and commercialization activities.
- Implementing a coordinated and aggressive statewide branding and marketing strategy.

7 – SWOT(Strengths Weaknesses Opportunities Threats) Analysis

The Regional forums also reviewed and revised a SWOT analysis and the results follow. The strengths, weaknesses, opportunities and threats assessment of the Biotechnology Cluster shows the issues that Texas needs to address to move to the forefront of the biotechnology and life science industries nationally and around the world.

With significant assets in human, plant, animal and marine research and discovery, Texas has abundant basic and translational research – taking basic research and translating it to a commercial opportunity – and resources on which to leverage its knowledge for a highly competitive Biotechnology and Life Science Cluster. Yet the limiting factor for such success will be the inability to link disparate assets and resources into unique and innovative approaches for creating wealth, generating jobs, and ultimately growing the economy across a broader set of stakeholders.

Strengths	**Weaknesses**
• Existing research and healthcare facilities • Lower cost of living • Positive quality of life • Non-state dollars: Foundations and private wealth generous towards programs and buildings • Cohesive industry agenda • Depth of knowledge in key research areas attractive to Nobel prize and other award recipients • Awareness of the need for action among key stakeholders, and the willingness to create and implement innovative solutions • Expertise in several key areas needs to be focused and marketed • Infrastructure is an asset to be leveraged • Breadth and depth of patient base is a valuable resource to be acknowledged.	• Venture capital unwilling to invest in the transfer of biotechnology from the lab to the market • Investors unaware of opportunities and potential reward for investing in Texas' biotechnology and life science cluster • Investment dollars missing for early stage enterprise • Insufficient funding in certain school systems, at all levels • Legislative/Institutional barriers • Missing a coordinated state strategy to develop efficient technology transfer • Regional competition overwhelms opportunity to collaborate • Need experienced senior managerial talent and processes that facilitate commercialization of technology by the private sector • Lack of focus on competitive advantages - Texas tries to be all things to all people
Opportunities	**Threats**
• Significant long term and rapid growth in life science industry • Economic models are undergoing rapid change • New trends in Texas' Life Science • Changing demographics lead to opportunities in personalized medicine and increased clinical trials • Increased awareness among private and public sector or the advantages of fostering growth in biotechnology and life science industries • Biodefense, health-related homeland security • Attracting biotech and large scale pharma companies looking to relocate from other areas • Nanobiotech, genomics and personalized medicine	• Funding goes elsewhere • Increased global competition among universities • Rapid change in demographics • New trends in Life Science • Increasing inter-state competition for business revenues, research investment dollars and life science jobs • Heavy investment by competing states to monopolize stem cell research and recruit Texas based researchers • Lack of emphasis on applied research and technology commercialization within institutions • Inadequate global awareness of Texas to key constituencies

8 – Targets of Opportunity

Vital to becoming competitive in the current technology-focused and agile economy is the ability of Texas to leverage current strengths and opportunities to achieve excellence and become a global leader. Given the breadth and competitiveness of the Biotechnology Cluster, it is impossible to excel in every area. Targeting will allow Texas to hone in on a particular field and gather the specialized resources, talent, and assets necessary to become a premier destination for educators, scientists, researchers, entrepreneurs, investors, corporations and workers interested in a specific facet of the industry.

To take full advantage of the targets of opportunity, Texas must purposefully choose to rationalize its resources based on significant strengths compared to other states. Five targets of opportunity evolved from the Biotechnology and Life Science Cluster Assessment and are as follows.

- Agricultural biotechnology: plant, animal, & marine
- Drug development, delivery, and vaccines
- Health-related information technology
- Health-related homeland security
- Medical devices

Targets of Opportunity	
Target	**Agricultural biotechnology**
Definition	The use of biotechnology to improve the production of crops and livestock towards agricultural, rather than human therapeutic ends.
Market Size Estimate	The US market for plant biotechnology was worth $1.6 billion in 2001, and the world market was worth $3 billion in 2000.[xvii]
Leading Technologies	Bio-pharming/molecular farming: The practice of cultivating transgenic crops to produce industrial chemicals and pharmaceutical proteins, such as vaccines, hormones, blood clotters, blood thinners, antibodies and contraceptives. The global industry for "plantibodies" and "plantigens" (human antibodies and antigens made by and in transgenic plants) could exceed $100 billion by 2015.[xviii]
	Nutraceuticals: The U.S. market for nutraceuticals, or foods that are enhanced with vitamins, herbs and nutritional supplements, was $46 billion in 2002, and is expected to grow to more than $74 billion by 2007.[xix]
	Genetically-modified seeds: Nation-wide, the seed industry is valued at about $6 billion annually, or 20% of the $30 billion annual world seed industry.[xx] World demand for transgenic seeds is expected to grow by 12% annually.[xxi]
	Scientists at the Human Genome Sequencing Center at the Baylor College of Medicine, in cooperation with the NIH, the USDA, and researchers from Canada, Australia, and New Zealand, have successfully sequenced the bovine genome, and have made the results freely available to scientists worldwide.[xxii]
Opportunities for Texas	Sire selection – advanced techniques using genetics to enhance breeding. Calf evaluation – provide best performing calves with best nutrition Applying genomic information to identify disease processes and improved treatments. Expanding upon electronic database to track animal heritage and trace delivery to market. Veterinary pharmaceutical research (R&D expenditures for veterinary-use pharmaceuticals was $307.3 million in 2002, $247.6 million of which in the U.S.)[xxiii]

Target	Drug Development / Delivery / Vaccines
Definition	Delivery challenges are increasingly important in developing new pharmaceuticals. Many of the newer, biotechnology-derived drugs face delivery challenges not seen in the prior generation of small-molecule synthetic pharmaceutical drugs.
Market Size Estimate	The pharmaceutical industry has approximately 223,000 employees nationwide. Total pharmaceutical company sales equaled about $196.7 billion in 2002, of which $145.2 billion, or 73.8%, was represented by the U.S. market.[xxiv] Total investment in R&D by the pharmaceutical industry was $33.2 billion in 2003 (more than four times the investment in 1990), about 80% of which was in the U.S.[xxv]
Leading Technologies	Monoclonal antibodies, Aptamers, RNA therapeutics, Transdermal delivery, Vaporization/atomization and lung delivery, Implantable drug-eluting devices, Gene therapy, Antibody vaccines.
Opportunities for Texas	Novel delivery methods are required to effectively deliver therapeutic doses to their targets. These delivery systems can also benefit existing drugs, facilitating administration and improving safety and efficacy.
	Finding ways to reduce the 12-15 year cycle time and the roughly $800 million cost to bring new drugs to the market.[xxvi]
Target	**Health-Related Information Technology**
Definition	The utilization of telecommunication technology for medical diagnosis, treatment and patient care.[xxvii]
Market Size Estimate	Total federal grants in 2003 equaled $270 million, 1/3 of which came from the Defense Department.[xxviii]
Leading Technologies	Store-and-Transmit Telemedicine, Real-time video linking, Personal Status Monitor (PSM) assistance, Electronic Disease Reporting & Management System (EDRMS)
Opportunities for Texas	Telemedicine is revolutionizing radiology, pathology, cardiology, medical education, and other disciplines. It promises to improve the quality, increase the efficiency, and expand the access of the healthcare delivery system in Texas, especially in rural areas.[xxix]
Target	**Health-Related Homeland Security**
Definition	Includes products and services designed to help prevent or detect a biological or chemical attack, or to inoculate, diagnose, or treat victims of such an attack.
Market Size Estimate	The federal government estimates global demand for security products and services will triple by 2010, reaching nearly $400 billion; 1/10 will be R&D. Total federal R&D on homeland security is about $10 billion annually. Project BioShield alone is worth $5.6 billion over ten years.
Leading Technologies	Wi-Fi, nanotechnology, robotics & remote devices, chemical and biological warfare sensor devices, Monoclonal Antibodies, bioinformatics.
Opportunities for Texas	The University of Texas Medical Branch at Galveston (UTMB) was selected by the National Institute of Allergy and Infectious Diseases (NIAID) as the site of a $150 million National Biocontainment Laboratory (NBL), one of two in the nation.[xxx] The new facility will contain 83,000 sq ft. of lab space. In addition, UTMB at Galveston has been awarded a $48 million grant from the Department of Health and Human Services (HHS) establishing a Regional Center of Excellence for Biodefense and Emerging Infectious Diseases Research (RCE).[xxxi] The technology developed for these and other homeland security applications has crossover commercial potential, including in medical and veterinary diagnostics and therapeutics.

Target	Medical Devices
Definition	The medical device industry includes both low and high technology products for the delivery of healthcare services.
Market Size Estimate	The worldwide medical device business had sales of $190 billion in 2002, which was expected to have increased by 15% by the end of 2004.[xxxii] There are about 5177 medical device manufacturing establishments in the United States, employing about 308,614 people.[xxxiii] There are about 272 medical device manufacturing establishments in Texas (roughly 5.3% of the US total), employing about 14,267 people (roughly 4.6% of the US total).[xxxiv]
Leading Technologies	Surgical and medical instruments, electro-medical equipment, irradiation apparatus, biopolymers, in vitro diagnostic substances. With the expansion of nanotechnology, the medical device industry is becoming intertwined directly with biotechnology, as nano devices are developed for the delivery of biological agents.
Opportunities for Texas	The medical device industry is export-heavy: over half of all devices produced in the US are exported. As the largest exporting state in the U.S. ($99 billion in goods and services in 2003), Texas is ideally suited to take advantage of this market.[xxxv] Wages in medical device manufacturing are roughly 20% higher than in average manufacturing jobs.

9 – Implementation

Ensuring the "Right to Win" — Texas' State Efforts

Emphasis must be placed on implementation statewide – regional champions must collaborate to develop an agreed to action-oriented strategic plan that leads to long term economic and societal benefits. The Biotechnology Cluster team is committed to facilitating and leading that process.

Further Recommendations

- Using a set of rigorously developed performance metrics, Texas must "set the bar" and define where and how its public investment will reap both economic and societal returns.

- The state must organize and support an industry/state partnership, across all regions, that is composed of all educational institutions (K-12, post-secondary and graduate, adult education, state agencies, workforce boards and one-stops), organized around the current and future training needs of the Biotechnology Cluster.

- Texas must pursue the various "targets of opportunity" within the cluster where its unique strengths give it a competitive advantage. Specifically, the importance of animals and plants to the statewide economy calls for an increased focus on those sectors as platforms for scientific and technological innovation.

- Through the cluster process, Texas should design a new workforce framework that is consistent in its focus, broadly communicates a more proactive delivery system, and has a regular follow-up process to determine adjustments and alignments.

- Texas should produce a Strategy for Action that has three critical ingredients –
    - Internal Focus – it identifies existing and anticipates future state resources based on current and future employer, Biotechnology Cluster needs.
    - External Focus – it promotes to the global industry, likely to consider expanding or relocating to Texas, the anticipated response since the new Texas workforce model is flexible, efficient and anticipatory to their future needs.
    - Sustainable and Scalable – it creates an overarching framework for the design and delivery of a new workforce delivery system – and then identifies the means to scale best practices and best principles on a sustainable basis.

- Curricula should be certified by industry for both immediate and anticipated needs.

- Texas should identify and launch two or three pilot projects around regional and statewide workforce academies funded by federal, state, industry, private foundations and economic development sources likely based on successful models already operating at the local level.

Throughout the Biotechnology Cluster team assessment process, we heard additional recommendations for implementation that were particularly workforce and education focused:

- Document the existing resources for the Biotechnology Cluster immediately, and create a dedicated web site that links and posts this information.
- Develop a mechanism for keeping information current.
- Encourage the Texas Higher Education Coordinating Board to facilitate statewide articulation agreements between education and training institutions that include workforce programs and not just academic programs.
- Increase public awareness of career lattice opportunities starting in middle school through adults transitioning into new positions.
- Promote programs where industry trains the trainer while training the students.
- Disseminate bioscience research and industry activities to educational partners through interactive websites, workshops, adopt a school and mentoring activities.
- Create paid internship opportunities for both faculty and students starting at the high school level.
- Create incentives for companies and training institutions to partner.
- Provide scholarships for students of *all ages* entering career lattices.

All of these recommendations are relevant to all of the industry clusters and should be the focus of cross cluster teams that would design and implement them for Texas.

Texas Next Steps to Success

To succeed, the life science biotechnology cluster needs a critical mass of intellectual capacity, talent, and skills in specific industries. Texas has that. While Texas has invested in physical infrastructure, it needs to match the changing requirements of evolving technologies and the pressure to accelerate the process from lab discovery to market commercialization. This acceleration requires an infusion of smart capital at the opportune moment to improve success. **A combination of initiative, advocacy and will can make the difference between lackluster performance or Texas' success. It can create the "Right to Win" in the Biotechnology and Life Sciences Cluster.**

10 – Texas Biotechnology and Life Science Cluster Team

The Texas Biotechnology and Life Science Cluster Team is chaired by Mae Jemison, M.D., Founder and CEO of BioSentient Corp. Cluster Team members, contributors and assessment participants include:

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