FINAL REPORT

PLATFORM FOR PROGRESS:

ARIZONA'S BIOSCIENCE ROADMAP

PREPARED FOR:
Flinn Foundation

PREPARED BY:
Technology Partnership Practice
Battelle Memorial Institute
Cleveland, Ohio

December 2002

Battelle
The Business *of* Innovation

Platform for Progress:

ARIZONA'S BIOSCIENCE ROADMAP

Prepared by:

Technology Partnership Practice

Battelle Memorial Institute

December 2002

Table of Contents

Table of Contents (continued)

Page

List of Figures

Table of Contents (continued)

Page

List of Tables

Table of Contents (continued)

Page

Abbreviations and Acronyms

ADCRC	Arizona Disease Control Research Commission
ASU	Arizona State University
ADOC	Arizona Department of Commerce
ARP	Advanced Research Program
ATP	Advanced Technology Program
BCMT	Baylor College of Medicine Technologies
CEDC	Community and Economic Development Commission
CRI	Cancer Research Institute (at ASU)
FAST	Federal and State Technology
FDA	U.S. Food and Drug Administration
GRA	Georgia Research Alliance
GSP	gross state product
IGC	International Genomics Consortium
IP	Intellectual Property
IPO	initial public offering
MCC	Microelectronics and Computer Consortium
MIPL	Multidimensional Image Processing Laboratory
MRI	magnetic resonance imaging
NAFTA	North American Free Trade Agreement
NAICS	North American Industry Classification System
NAU	Northern Arizona University
NCI	National Cancer Institute
NCTDA	North Carolina Technological Development Authority
NIAID	National Institute of Allergy and Infectious Diseases
NIDDK	National Institute of Diabetes, Digestive and Kidney Diseases
NIEHS	National Institute of Environmental Health Sciences
NIST	National Institute of Standards and Technology
NMR	nuclear magnetic resonance
OTCC	Oklahoma Technology Commercialization Center
R&D	research and development
SBA	Small Business Administration
SIC	Standard Industrial Classification

SWOT	strengths, weaknesses, opportunities, and threats
TGen	Translational Genomics Research Institute
UA	University of Arizona
USDA	U.S. Department of Agriculture

Executive Summary

INTRODUCTION

Now is an opportune time for Arizona to initiate bold action to ensure long-term prosperity for its citizens through a comprehensive partnership of its private and public sector leadership to build Arizona's future in selective fields of the biosciences. In recent months, much public attention and momentum has resulted from Arizona's successful efforts to attract the Translational Genomics Research Institute (TGen) and the International Genomics Consortium (IGC). However, TGen and IGC are but one anchor of a much broader set of strategies and actions that will be necessary to position Arizona as a major southwest bioscience center over the coming decades. To address this issue, Arizona's leaders are seeking to develop strengths in those technology areas expected to lead future economic growth—chief among them is the bioscience sector.

This Roadmap Alliance lays out a comprehensive approach to accomplish this plan, with details in the full report and highlights in this executive summary. This Roadmap proposes a bioscience agenda based on private sector market-driven needs, and recommends actions that are implemented around filling private sector gaps through private-public partnerships, led by industry.

Arizona must play "catch up" to other states in building a world-class research base, as well as translating this base into clinical care, treatment, and commercialization of technology through building a critical mass of bioscience-related firms. This Roadmap identifies three near-term technology platforms in which the state's research universities and related medical and other research organizations have existing and emerging strengths on which to build—neurological sciences, cancer therapeutics, and bioengineering. Focusing on key platforms—rather than trying to spread limited resources across multiple areas—may be the best approach for Arizona to catch up and excel in key research areas, the absolute prerequisite to improved quality health care delivery and creation of well-paying jobs.

Arizona has reached a critical first phase in building momentum in the biosciences. Translational research linking bench to bed and classroom can "fast track" Arizona on this path to bioscience stature. Technology commercialization must be concurrently addressed if the state is to build a critical mass of bioscience firms and to apply research to patient care and quality health care delivery. Arizona's current situation is not unique. Other states and regions once behind in the development of their bioscience sectors (including San Diego, California; Montgomery County, Maryland; Birmingham, Alabama; and Portland, Oregon) have either successfully positioned themselves as a leading bioscience region or are focusing their strategic investments to carve out a particular market niche for the future.

ARIZONA'S BIOSCIENCE VISION

With strong public and private leadership and long-term commitment, Arizona can achieve the following vision in the next 10 years:

> ***Arizona is a leading southwestern state in selective bioscience sectors, built around world-class research, clinical excellence, and a growing base of cutting-edge enterprises and supporting firms and organizations.***

MISSION

To achieve this vision, Arizona must approach its future in the biosciences by

- **Further investing in and building Arizona's world-class research and clinical and product excellence around selective bioscience sectors. The goal is to have Arizona's growth rate in National Institutes of Health (NIH) research funding comparable to that of the top 10 states in the nation by 2007.**
- **Putting in place mechanisms, programs, and incentives that encourage research to be turned into products, processes, and wealth generation for the state and its citizens. Vehicles must be in place to accelerate the ability to "mine" a growing research and development base for commercial and technological development.**
- **Mobilizing public and private leadership and increasing citizen knowledge and understanding of the biosciences and its impact on health and safety, teaching and research, and economic development (bench, bed, and classroom).**
- **Building "trees of talent" by encouraging scientific and technical talent to be developed and retained in the state.**

Arizona has the potential to develop its leadership in key focused bioscience technology platforms, but developing the biosciences in Arizona will require

- ***Patience and a long-term commitment***. One lesson from every successful technology community is that success takes time. Developing a bioscience sector cannot be accomplished in a year or two. It requires a long-term effort, measured in a decade or more.
- ***Champions.*** To be successful, the development of the biosciences in Arizona must have champions—leaders with the ability to bring all of the relevant players to the table and the means to see that the strategic recommendations are implemented.
- ***Strategic focus.*** Successful states and regions have recognized that they have neither the capacity nor the assets to excel in all areas of technology. Instead, they have examined their comparative advantages, within both their industrial and research bases, and focused their investments on competitive niches in which they can and do excel.
- ***Strong public-private partnerships.*** Growing a state's bioscience sector requires collaboration and strong working partnerships between and among the state's higher education, industry, nonprofit, and philanthropic leaders. Those leading states and regions in the biosciences and other technology fields have established highly linked and interactive

processes in which research excellence and a growing industry base are pursued simultaneously in a highly connected manner, supported with private, foundation and public investments.

- ***Active state and local government support.*** The federal government is widely recognized as the principal driver of basic research in the United States. Therefore, what is the role of state and local government? The state and local role is to ensure that the required infrastructure, such as research facilities, faculty, and physical infrastructure, is in place to leverage federal dollars. Their economic development role is to help find solutions to fill market gaps in ways that support, spur, link, and leverage ongoing private investments. These economic development efforts include focusing on public supported research universities; addressing the future talent pool through education and workforce programs; and ensuring a high quality of life, including a sound tax and regulatory climate. A related but important role of state government is improving the quality and access to health care within its borders, including research that translates into health care practice and treatment.
- ***Willingness on the part of the state's research institutions to partner.*** In today's competitive bioscience field, no one research entity will be able to "go it alone" effectively. For real success to occur, research institutions will need to partner to leverage resources, funding, and scarce knowledge assets.

WHY BIOSCIENCES IN ARIZONA?

Arizona has experienced tremendous population and economic growth during the past decade. Between 1995 and 2001, the state's population grew by 23 percent. Arizona's economy has grown just as rapidly, and the state has made progress in attracting and retaining technology jobs in the electronics and aerospace sectors. However, Arizona has not yet developed a diversified knowledge-based economy. Arizona ranks below average, for example, in terms of the number of residents working in knowledge-intensive sectors of the economy.[1]

Reasons for focusing on the development of the biosciences in Arizona include the following:

- *The bioscience sector is one of the fastest growing and most dynamic sectors of the economy*. Advances in the biosciences are likely to be a primary driver of future economic growth, when combined with their convergence with information technologies.
- *Bioscience research will lead to advances that will improve the health and quality of life of Arizona residents*.
- By virtue of its size and diversity, *the bioscience sector offers the opportunity to create new firms, high-wage jobs, and income, thereby creating wealth for Arizona citizens.*
- *The bioscience sector can build on Arizona's existing manufacturing and information technology strengths in fields such as electronics and optics.*
- *The bioscience sector can bring stability to Arizona's economy*, necessary to balance more cyclical industries such as travel and tourism.

[1] Morrison Institute for Public Policy. *Arizona Policy Choices 2001: Five Shoes Waiting to Drop on Arizona's Future*, October 2002, p. 28.

- *The bioscience sector offers employment opportunities across a broad range of occupations, thereby providing jobs for Arizona residents at various skill levels*.

In summary, Arizona's elderly and growing minority population bases will demand quality health care, which itself will benefit from the fruits of medical research and the availability of talented health workers – from technicians to postdoctoral fellows. Growth in the medical device, agriculture, and other biotechnology sectors offers job opportunities for these graduates so they may remain in Arizona and become employed in well paying jobs.

METHODOLOGY

But, can Arizona succeed in growing its bioscience sector and, if so, what will it require? In 2002, the Flinn Foundation engaged Battelle Memorial Institute's Technology Partnership Practice (TPP) to assist the Foundation and its partners, which include the Arizona Department of Commerce, the state's universities and medical institutions, local development organizations, and the business community, in developing a Bioscience Roadmap to grow the biosciences in Arizona. Battelle is one of the world's largest nonprofit research and development organizations. TPP assists public and private sector organizations seeking to grow their economies through technology-based economic development.

What will it take to grow the biosciences in Arizona? To answer this question, the Battelle team

- Conducted an **economic analysis** of Arizona's existing bioscience industry, identifying trends, current strengths, emerging industries, and emerging clusters within the bioscience complex.
- Prepared a **benchmarking analysis** that compares Arizona with other states that either are or are striving to become leading bioscience centers.
- Assessed Arizona's position in bioscience research and identified technology areas for future development through a **core competency review.**
- Identified **barriers to and gaps** in private and public investments, policies, programs, and activities that might hinder Arizona's ability to become a leading state in the biosciences.
- Developed this Roadmap that lays out a **vision** for the biosciences in Arizona and identifies the **strategies and actions** necessary to achieve this vision.

ARIZONA'S BIOSCIENCE INDUSTRY BASE

Arizona possesses an economic base in the biosciences that is small but rapidly expanding, outpacing national growth trends.

Arizona's bioscience employment base[2] has grown nearly 80 percent over the past six years, now consisting of approximately 450 establishments employing 9,100 workers. As a result, Arizona's location quotient has increased from 0.38 in 1995 to 0.48 in 2002. This is a significant increase, although Arizona remains more than 50 percent under concentrated in the biosciences than is the nation as a whole.

Growth in the Arizona bioscience sector is widespread, with each of the five bioscience subsectors outpacing the nation in terms of employment increase, indicating the breadth of opportunity in the sector.

The biosciences can be organized into five subsectors: drugs; organic and agricultural chemicals; medical devices and instruments; hospitals and laboratories; and bioscience research and testing. Examining these five subsectors reveals that Arizona employment growth has exceeded the national pace in each of the five bioscience subsectors between 1995 and 2001, in several cases by a large margin. For instance, growth in organic and agricultural chemicals was 186.6 percent higher in Arizona than in the nation, and employment expansion in medical devices and instruments was 45.4 percent higher (Table ES-1). Excluding hospitals and laboratories, Arizona's bioscience sector posted a six-year employment gain of 79.4 percent, compared with 28.3 percent for the entire nation.

Table ES-1. Arizona Bioscience Subsector Concentrations and Growth Rates

Subsector	2001 Employment	Location Quotient	%-point Difference between AZ and U.S. Empl. Growth '95-'01
Hospitals & laboratories	62,775	0.78	16.0
Medical devices & instruments	4,141	0.60	45.4
Organic & agricultural chemicals	1,896	0.70	186.6
Drugs	1,601	0.23	2.6
Research & testing	1,463	0.59	39.6
BIOSCIENCE SECTOR	71,876	0.72	17.3

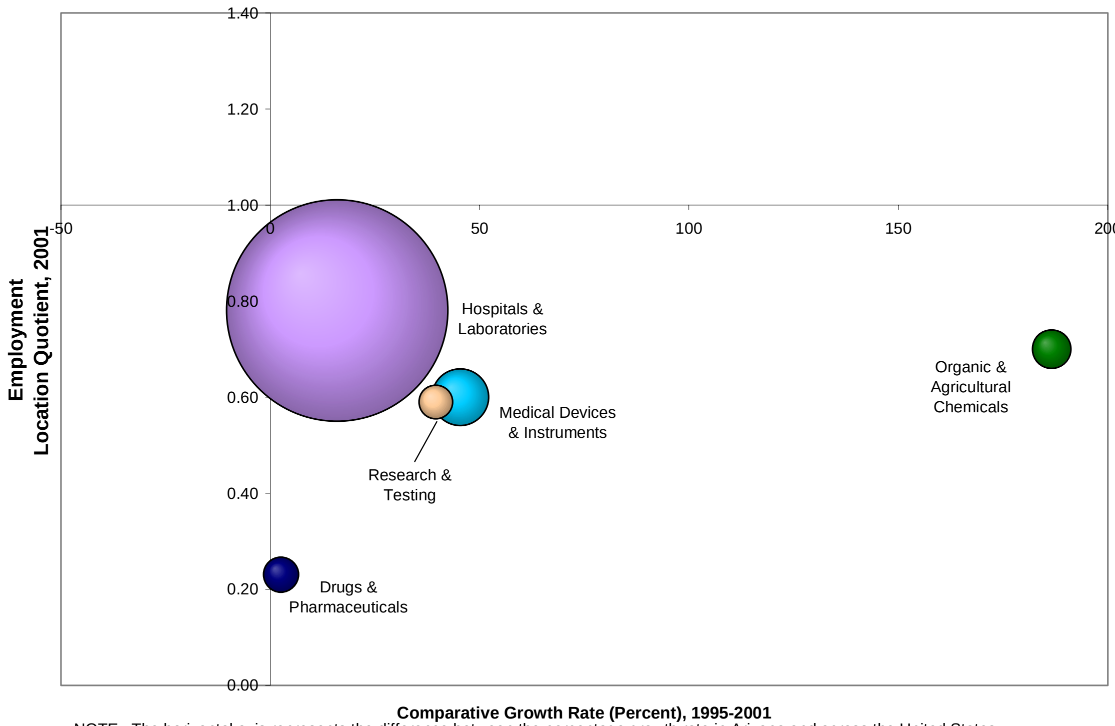
However, Arizona is 28 percent less concentrated in the biosciences overall than the rest of the nation. None of the bioscience subsectors exhibits a location quotient larger than 0.78, illustrating that Arizona lags the national level of bioscience industry presence across all of the subsectors.

Overall, Arizona's bioscience subsectors are in an emergent period, possessing certain specific strengths, sustaining remarkably rapid growth, but not as yet transformed into a fully mature economic sector. To provide a visual comparison of their various characterizations, Figure ES-1 classifies the five Arizona bioscience subsectors according to employment size, comparative growth rate, and relative concentration. The area of each disk corresponds to

[2] Excludes the hospital and laboratory subsector.

the amount of employment in that subsector. Each of the five bioscience subsectors falls into the bottom right-hand quadrant of the graph, with lower concentrations but faster employment growth rates than across the United States, thereby representing an emerging strength. Vibrant, mature sectors, those that have a greater concentration than the nation while still maintaining a faster growth rate, are found in the upper right-hand quadrant. From a policy standpoint, the goal is to move emerging industry sectors found in the lower right-hand quadrant into the upper right-hand quadrant.

Figure ES-1. Characteristics of Arizona Bioscience Subsectors



NOTE: The horizontal axis represents the difference between the percentage growth rate in Arizona and across the United States.

Arizona's existing and emerging strengths in electronics, information, optics, and materials represent an advantage for its efforts in the biosciences. These areas are increasingly converging with the biosciences, resulting in new technologies that provide the state with niche market opportunities around technology convergence.

The trend toward convergence of technologies in electronics, information, optics, materials, and the biosciences creates a potential competitive advantage for Arizona. The existence of a strong information technology cluster in the state could provide a nucleus for achieving the needed critical mass in the biosciences. Experts widely agree that these areas will converge, thereby producing a new generation of technological products that embody elements of all the fields. The application of electronics, optics, and materials to biotechnology products has been evolving rapidly; and the convergence of the biosciences and information technology has led to the emergence of companies bridging the health care and Internet economies. Arizona is well positioned to benefit from these trends.

ARIZONA'S BIOSCIENCE RESEARCH BASE

Despite a sizable base, Arizona is behind in the bioscience research arena.

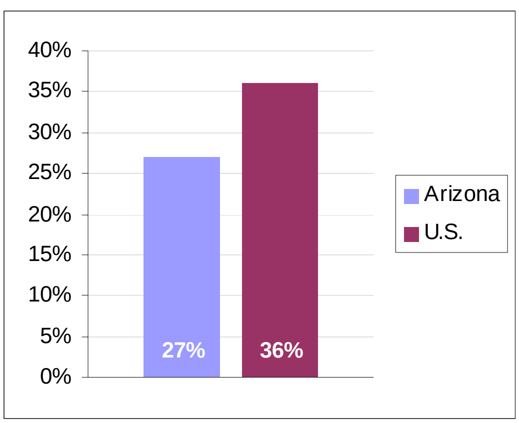
The biosciences account for $229 million of university research in Arizona, or 44 percent of the university research base in the state. This falls far short of the national average of 57 percent that biosciences account for of total university research. Not surprisingly, Arizona's national ranking in university-based bioscience research is 27th in the nation, compared with its overall research ranking of 21st. Furthermore, total bioscience research grew only 27 percent in Arizona from 1996 to 2000, compared with 36 percent for the nation, meaning Arizona is losing market share of national research dollars. More startling is the fact that Arizona's growth rate was less than every other benchmark state.

Benchmark Growth Rates

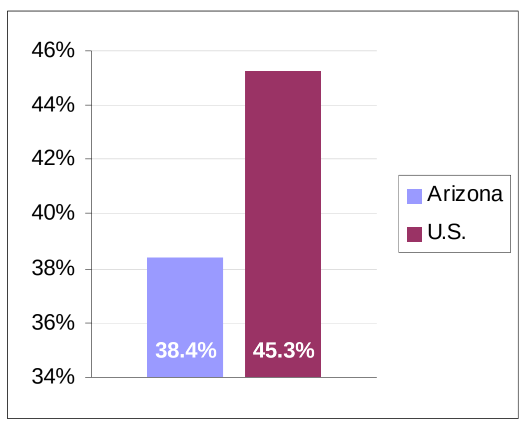
- Utah – 64.3%
- San Diego – 52.4%
- North Carolina – 42.0%
- Texas – 41.3%
- Colorado – 40.9%
- United States – 35.7%
- Washington – 33.8%
- Oregon – 32.1%
- Oklahoma – 30.5%
- Georgia – 29.2%
- Arizona – 27.5%

NIH funding—the gold standard of biomedical research funding, which includes funding to non-university entities—is also lagging in the State of Arizona (Figure ES-2). For FY 2001, Arizona received $117 million in NIH research funding, placing the state 27th in the nation. Growth in NIH funding from 1997 to 2001 stood at 38.4 percent in Arizona, compared with 45.3 percent for the nation.

Figure ES-2. Arizona is Lagging Growth in Bioscience Research in Late 1990s



University Bioscience Research Growth from 1996 to 2000



NIH Bioscience Research Growth from FY 1997 to 2001

Arizona's research institutions and medical centers have key core competencies in the biosciences that can be leveraged to establish platforms in which Arizona can gain national prominence over the next five years.

Battelle undertook both a research core and technology platform competency analysis, including quantitative and qualitative reviews of research strengths, existing and emerging, on which Arizona can build its bioscience base. Research core competency refers to those research areas where both concentration of activity and excellence are demonstrated by having

- A significant number of bioscience-related research grants awarded through rigorous peer-review processes such as those at NIH, National Science Foundation (NSF), and the U.S. Department of Agriculture (USDA).
- A broad base of principal investigators, along with prominent biomedical researchers who hold multiple peer-review grants.
- Substantial level and impact of publications.

The analysis revealed that Arizona has key core competencies around which to build bioscience technology platforms. Arizona has a strong core of expertise in neurological sciences (e.g., Alzheimer's, epilepsy) within its universities and medical centers; expertise in cancer research, particularly in the area of advancing innovative new cancer therapies (e.g., pancreatic, colon); and strengths in the physical sciences, which provide a strong base upon which to pursue bioengineering applications (e.g., imaging, prosthetics). Four other platforms that offer the potential for growth over the long term are primarily disease-specific: infectious diseases, agricultural bio-technology, asthma, and diabetes. Table ES-2 provides a summary of technology platforms that offer the greatest potential to build Arizona's bioscience base.

Near-Term Technology Platforms

- Neurological sciences
- Cancer therapeutics
- Bioengineering

Long-term and Niche Technology Platforms

- Infectious Diseases
- Agricultural Biotechnology
- Asthma
- Diabetes

Table ES-2. Technology Platform Linkages Across Core Competencies: Current and Emerging

Technology Platform	Basic Research	Enabling Technology	Applications
Areas Judged by Battelle to Have Near-Term Growth Potential Over Next Five Years			
Neurological Sciences	Neurobiology	Neural Engineering Motor Control Imaging Clinical Research Insect Science	Alzheimer's Disease Parkinson's Disease Epilepsy Rehabilitation
Cancer Therapeutics	Genomics (with new IGC/TGen)	Drug Discovery Clinical Research	Anticancer Drugs Pancreatic Cancer Colon Cancer Environmental Links to Cancer
Bioengineering	Physical Sciences	Bioengineering Optics Materials Analytical Chemistry Electronics Imaging Computer Science	Imaging & Diagnostics Implants Prosthetics Robotic Systems
Areas Judged by Battelle to be Opportunities for Future Development			
Infectious Diseases	Microbiology	Plant Vaccine Development Ecology & Evolutionary Biology	Anthrax, Plague, and Other Pathogens Plant Vaccine Development Valley Fever
Ag-Biotech	Plant Genomics		Crop Development Nutraceuticals
Asthma	Genetics	Clinical Research	Asthma
Diabetes		Clinical Research Stress Research	Diabetes

From electronics to optics, Arizona has proven it can transform itself into national research prominence in non-bioscience research areas and, with it, enjoy the benefits of sharing in new economic drivers. In recent decades, Arizona has established itself as a national leader in key areas of natural science research, particularly astronomy, other physical sciences, and earth sciences/ecology. If Arizona's research universities can replicate the tremendous success they have had in the natural sciences, then the state's research universities can reverse the recent period of slower growth in their overall research growth relative to the nation that has occurred in the late 1990s. Focusing on the biosciences can have a substantial impact on Arizona's research base.

ARIZONA'S COMPETITIVE POSITION

The San Francisco Bay Area, Boston, the Baltimore/Washington region, the New York/New Jersey metro area, and San Diego are generally regarded as the nation's premier bioscience centers. An examination of the factors that have enabled these regions to succeed in growing their bioscience bases shows that they share a number of characteristics. They include

Key Success Factors

- Engaged universities with active leadership
- Intensive networking across sectors and with industry
- Available capital covering all stages of the business cycle
- Discretionary federal or other R&D funding support
- Workforce and talent pool on which to build and sustain efforts
- Access to specialized facilities and equipment
- Stable and supportive business, tax, and regulatory policies
- Patience and a long-term perspective

- ***Engaged universities with active leadership.*** An outstanding research university is required to become serious about the biosciences. But, it takes more than simply research stature. It requires the capability to engage industry, directly or indirectly, to convert this intellectual knowledge into economic activity. To do so requires one or more of a region's research universities committed to engage with and help build and sustain a bioscience community locally. The leadership of Arizona's universities has demonstrated a willingness to collaborate in support of developing the state's bioscience sector and is initiating policies and programs to improve technology transfer and commercialization. These are important first steps in creating the type of university-industry relationships found in other leading bioscience centers.
- ***Intensive networking across sectors and with industry.*** As many observers of high-tech clusters have noted, the most successful clusters facilitate extensive and intensive networking among technology companies and their managers and employees. In a very few leading communities like Silicon Valley, this networking has occurred naturally, with formal organizations like Joint Venture-Silicon Valley coming only later. However, in the vast majority of American regions, such organizations need to be built from the ground up; otherwise, the desired degree, scale, and intensity of networking will not occur. Arizona does not yet have a critical mass of bioscience companies or sufficient networking and mentoring.
- ***Available capital covering all stages of the business cycle.*** Leading bioscience regions share one characteristic: they are home to a venture capital community that is both oriented toward early-stage financing and committed to local investment. Having state-based local venture capital funds with experience investing in bioscience companies is critical. It is also critical to have financing available for each stage of development from early-stage, proof-of-concept, and prototype development to product expansion and later-stage venture financing. While a number of Arizona-based venture funds exist, several of which are investing in bioscience companies, a gap in pre-seed/seed stage funding for bioscience companies is generally conceded.
- ***Discretionary federal or other R&D funding support.*** To build generic R&D assets into an effective attractor of technology investment requires leverage of substantial, ongoing, external, discretionary funding. Technology leaders like Silicon Valley, Route 128 in the

Boston area, and San Diego were able to leverage decades of heavy defense contracting, while Baltimore/Washington leveraged growing congressional support of federal laboratories owned by NIH, the National Institute of Standards and Technology (NIST), and the Food and Drug Administration (FDA). In the absence of massive federal or corporate investment, most regions must use state funding as a lever for acquiring strategic external investments. The premise behind the investments made in TGen and the IGC is that additional federal bioscience funding will be attracted to Arizona.

- ***Workforce and talent pool on which to build and sustain efforts***. Like any knowledge-based industry, bioscience companies need a supply of qualified, trained workers. To meet the demands of newly emerging fields, new curricula and programs need to be developed by educational institutions working in close partnership with the bioscience industry. In addition to having world-class researchers, successful bioscience regions have an adequate supply of management, sales, marketing, and regulatory personnel experienced in the biosciences. While Arizona's universities and community colleges are producing graduates with degrees in the biosciences and bioscience-related fields, it is difficult to find managers and other workers experienced in the biosciences.
- ***Access to specialized facilities and equipment.*** Facility costs are among the most significant expenses of a new bioscience firm. These firms need access to wet-lab space and specialized equipment. Since most bioscience firms initially lease space rather than purchase it, an available supply of facilities (such as privately developed multitenant buildings) offering space and equipment (such as incubators and accelerators) for bioscience companies is critical. Arizona lacks bioscience incubators, accelerators, and research parks and has inadequate wet-lab facilities.
- ***Stable and supportive business, tax, and regulatory policies.*** Bioscience companies need a regulatory climate and environment that encourage and support the growth and development of their industry. Tax policies that recognize the long development cycle required to bring new bioscience discoveries to the market can provide additional capital for emerging companies, as well as ensuring an even playing field in state and local tax policies between older, traditional industries and emerging industries such as the biosciences. Arizona's tax structure needs to be comprehensively reviewed to ensure that it has the incentives in place to encourage private sector bioscience investment and the growth of the industry.
- ***Patience and a long-term perspective***. One final lesson from every successful technology community is that success takes time. Silicon Valley and Route 128 trace their origins in electronics to the 1950s and in life sciences to the 1970s. Research Triangle Park represents a 50-year strategy that has only recently found its footing in the biosciences and is still working to develop full capability in the entrepreneurial sector. In contrast, Maryland has emerged as a major bioscience center in 12 to 14 years. While this may indicate that the time required to become a leading bioscience center can be shortened, it must be recognized that such development cannot be accomplished in a year or two or around a single project. It requires a long-term effort.

Table ES-3 summarizes how Arizona compares to best practice bioscience regions on the key success factors.

Table ES-3. Comparison of Arizona to Best Practice States and Regions on Key Success Factors

Factors of Success	Best Practice States/Regions	Arizona Situation
Engaged Universities with Active Leadership	✓ Universities are engaged in economic development and committed to technology transfer ✓ Have created vehicles for technology commercialization	✓ The leadership of Arizona's universities is committed to developing the biosciences and has entered into partnerships such as TGen ✓ Improvements have been made in technology transfer and commercial-ization, but greater investment is needed in vehicles for technology commercialization
Intensive Networking	✓ Active technology intermediary organizations provide a focal point for the state's biotechnology efforts ✓ These organizations play a critical role in networking academic, industry, government, and nonprofit groups, encouraging cross-fertilization of ideas and opportunities that lead to joint endeavors	✓ There are no active, professionally staffed industry organizations that have the ability to provide networking opportunities at the scale and intensity necessary to promote the emerging bioscience firms ✓ The state's existing bioscience cluster organizations are still in an early stage of development after several false starts
Available Capital	✓ Best practice states and regions have created programs to address the commercialization, pre-seed, and seed financing gaps to help establish and build firms ✓ Active informal angel networks investing in the biosciences ✓ Investors include private, philanthropic, and public entities	✓ A number of Arizona-based venture funds exist, several of which are investing in bioscience companies ✓ A gap in pre-seed/seed funding stage is generally conceded ✓ Limited angel networks are investing in the biosciences
Discretionary R&D Funding	✓ Every major technology region in the U.S. has received significant federal discretionary funding ✓ One or more federally designated centers exist that serve as anchors for the state or region's bioscience base	✓ Market share of NIH funding awards has decreased ✓ Limited success exists in obtaining federally designated bioscience centers ✓ Successful effort to attract IGC and TGen represents major accomplishment
Talent Pool	✓ Talent increasingly provides the discriminating variable for states and regions to build comparative advantage ✓ Educational institutions at all levels responsive to training students to meet the needs for bioscience workers at all skill levels including scientists, technicians, and production workers	✓ Arizona graduates are in excess of bioscience jobs available ✓ Strong interdisciplinary efforts exist at universities ✓ Strong community college system is offering increased curricula in the biosciences ✓ Weak K-12 system will limit ability to produce students who will pursue bioscience careers

Table ES-3. Comparison of Arizona to Best Practice States and Regions on Key Success Factors (continued)

Factors of Success	Best Practice States/Regions	Arizona Situation
Specialized Facilities and Equipment	✓ Leading bioscience regions have private markets that provide facilities offering space for bioscience companies ✓ Specialized bioscience incubators and research parks are common ✓ Access to specialized facilities and equipment, such as core labs, and animal facilities, is readily available	✓ Wet-lab space is insufficient ✓ No specialized bioscience research parks exist ✓ Incubator and accelerator space for bioscience companies is limited ✓ Knowledge of university equipment and facilities that could be accessed by firms is lacking
Supportive Business Climate	✓ Incentives to encourage growth of technology-driven firms through modernized economic development tool kit ✓ Tax structures generally leveled to treat technology-driven and manu-facturing firms evenly ✓ Established brand name/image around technology themes	✓ Arizona has few economic develop-ment assistance programs to attract, retain, and grow bioscience firms ✓ Arizona's tax structure is not favorable for the development of a technology-based economy ✓ Arizona's affordability, regulatory environment, and access to resources are better than on either coast ✓ Arizona does not have an image or brand as a high-technology center
Patience and Long-term Perspective	✓ Building a critical mass of bioscience firms takes many years or even decades ✓ While the early technology pioneers took 25 years to develop, more recent examples such as Maryland and San Diego took 12 to 14 years to mature	✓ Arizona does not have a history of long-term state investment in technology development ✓ Development of successful partnerships to pursue IGC and TGen suggest that public and private leaders are beginning to make a long-term investment to building Arizona's bioscience base

The Battelle team also identified the strengths, weaknesses, opportunities, and threats (SWOTs) facing Arizona in its effort to position itself in the biosciences. This was accomplished through interviews, small group discussions, several focus group discussions, review of other studies, and collection of secondary data. The findings from the SWOT analysis are presented below.

Strengths

- Small but rapidly expanding number of bioscience companies
- State and regional leadership engaged in and supportive of the biosciences—TGen, IGC, the Biotech Institute (UA), the Medical Research Building (UA, COM), etc..
- Strong history of entrepreneurship
- Business environment conducive to development
- High quality of life in terms of cultural and recreational amenities, climate, and affordability
- Major player in basic research areas complementary to the biosciences
- Existing state support for bioscience research
- Community colleges and universities offering bioscience curricula

Weaknesses

- Private sector base not heavily concentrated in the biosciences
- Low-performing K-12 educational system
- Losing market share of national bioscience research funding
- No strong tradition of commercializing technology or encouraging entrepreneurship by universities
- State lacks necessary ingredients for a bioscience entrepreneurial culture
- Insufficient bioscience-focused venture capital and angel investors
- Few economic development assistance programs and lack of public support for higher education
- Unfavorable tax structure
- Severe budget constraints
- Business service providers not strongly specialized in the biosciences
- No image as a high-tech center
- Lack of skilled bioscience workers
- Insufficient wet-lab space

Opportunities

- Arizona well positioned to grow its bioscience sector in niche market areas, particularly neurological sciences, cancer therapeutics, and bioengineering
- Increased federal funding for bioscience research provides opportunity to capture larger share of bioscience research dollars
- Arizona has existing medical, health, and academic resources on which to build
- A focus on translational research can create a unique niche for Arizona's bioscience base
- Arizona's educational institutions are increasingly producing more graduates in the biosciences
- Matchmaking services and support for critical mass of bioscience firms
- Growing commitment to technology commercialization at the state's research universities
- State's investments in TGen/IGC could be leveraged to create and enhance partnerships with bioscience companies
- Opportune time for bold action
- Proximity to other markets provides a unique comparative advantage, e.g., San Diego and Mexico
- Opportunity to create a bioscience corridor—Flagstaff to Tucson

Threats

- Other states are aggressively pursuing bioscience development
- Other universities are pursuing biosciences as a key area of focus for their future
- Lack of early-stage equity capital may deter entrepreneurial start-ups from starting or growing in the state
- Lack of support for emerging bioscience companies may result in their decision to move out of the state
- Arizona's leaders may have unrealistic expectations and fail to recognize that developing the biosciences will require a patient and long-term commitment

SITUATIONAL ANALYSIS

Arizona's challenges in building its bioscience base include the following:

- Strengthening its bioscience research infrastructure and achieving higher education research excellence
- Developing a critical mass of bioscience companies
- Mobilizing public and private sector leadership and improving citizen knowledge and understanding of the biosciences and their impact on both economic development and the health of Arizona's citizens.

Strengthening the Bioscience Research Infrastructure and Achieving Higher Education Research Excellence

The combination of increased competition from other states, Arizona's current rankings on and success in securing federal biosciences research dollars, and its current status as a third-tier or lower state in the biosciences means that it must find ways to rapidly build its research capacity and, as it does, capture more federal and other leveraged dollars. Sufficient public sector funds for "bricks and mortar" investments, e.g., capital investments, are part of the gap to be filled; but, the gap is broader than that. It also means sufficient public sector operating funds to recruit and attract Eminent Scholars; to offer competitive recruitment packages for emerging, young, talented biosciences faculty; and to build core labs and facilities that are competitive with other academic health and university research centers across the country.

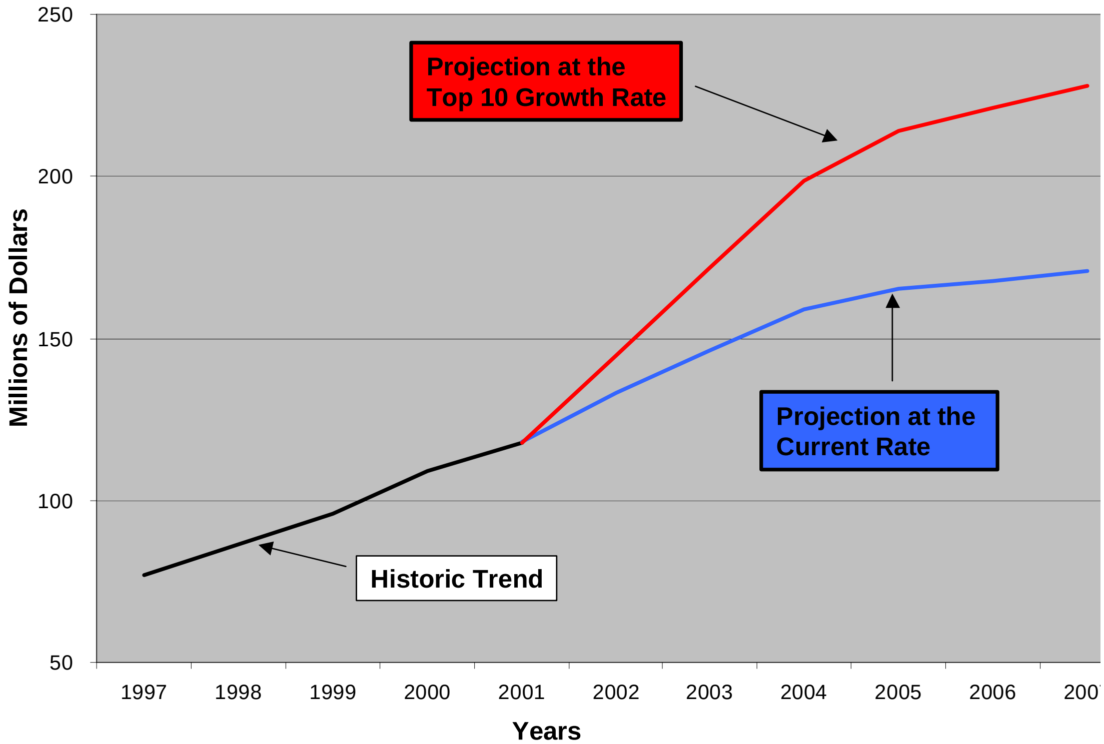
To address research infrastructure, Arizona must

- Focus on its core research capabilities and the platforms of neurological sciences, cancer therapeutics, and bioengineering over the coming five years.
- Work through multi-institutional collaboration, taking advantage of capabilities across research universities, hospitals and medical centers, and other research organizations to "jumpstart" Arizona, which is currently in a "catch-up" position.

Figure ES-3 projects Arizona's total NIH funding by the year 2007 if current trends continue. Whereas Arizona might see an increase in NIH funding from the current $118 million to $174 million, an increase of $56 million, Arizona would still place further behind other leading states. Alternatively, if Arizona is able to equal the growth rate in NIH funds of the top 10 states over the next five years, its NIH funding can increase by approximately $100 million to within the range of $214–$222 million. Arizona's performance goal should be to

> ***Achieve a rate of funding growth from the NIH equal to that of the top 10 states in NIH funding historically—increasing Arizona's NIH funding totals from $118 million in FY 2001 to $218 million in FY 2007.***

Figure ES-3. Projection of Arizona Total NIH Funding (FY 2001 to 2007)



Reaching this NIH performance objective will require corresponding investments by Arizona's research organizations in facilities, core laboratories, research faculty and support staff, and start-up packages to recruit such researchers and scholars. Table ES-4 lays out the financial implications for every $100 million in NIH funding achieved, based on national figures for costs of construction and recruitment as calculated by Battelle.

Table ES-4. Requirements to Support $100 million in NIH Funding

Estimate of One-time Requirements and Costs in Space, Research Groups, and Start-up Packages for Supporting Additional $100 Million in NIH Funding		
Estimate of	**Key Assumptions**	**Requirements**
Space Needs	For every additional $225 of research funding, need additional sq ft of space	444,444 sq ft
Space Costs	Costs $300 per sq ft for construction of basic research labs, not including core labs	$133 million
Core Research Labs	May include structural biology, micro-array facilities, animal facilities, etc.	$25–$50 million
New Research Groups	$900,000 in NIH annual funding per research group	111 research groups including senior PI, assoc. faculty, post-docs, research fellows
Start-up Package Costs	$2 million for start-up packages	$222 million, including equipment, supplies, etc.
Total One-Time Costs		**$380–$405 million**

Note: In addition, there will be ongoing operating costs for facility and for a portion of faculty salaries.

TGen and IGC represent a first installment in addressing the need to secure both additional federal research funds and funds for facilities, equipment, and other research infrastructure. These two organizations will increase the flow of federal NIH funds to Arizona both by recruiting researchers, who will bring funding with them, and by improving the capabilities of Arizona's existing research organizations to compete more successfully for NIH awards. The $90 million contributed by state, private sector, philanthropic, and university sources to attract TGen/IGC to Arizona will help Arizona partially meet the earlier-stated goal of an additional $100 million annually in NIH funding (perhaps by 25 percent). It will also help the state to partially address the additional $380–$450 million that will be needed around technology platforms to attract these federal funds.

Addressing Technology Commercialization and Building a Critical Mass of Bioscience Firm

The economic and gap analysis identified a range of issues that must be addressed concurrently with efforts to build a strong bioscience research infrastructure to turn this research into technology and realize the benefits commercialized in bioscience-related products and processes in the state, the nation, and the world. Areas such as the talent pool for the biosciences, capital gaps to finance and develop bioscience firms, space needs of such firms, networking and building an entrepreneurial culture, and educating the public and citizenry on the biosciences must be addressed as part of this Roadmap Alliance. Figure ES-4 identifies key gaps that must be addressed to grow Arizona's bioscience base. Figure ES-5 shows proposed actions that could be taken to address these gaps.

Figure ES-4. Arizona's Key Gaps Along the Life Science Development Continuum

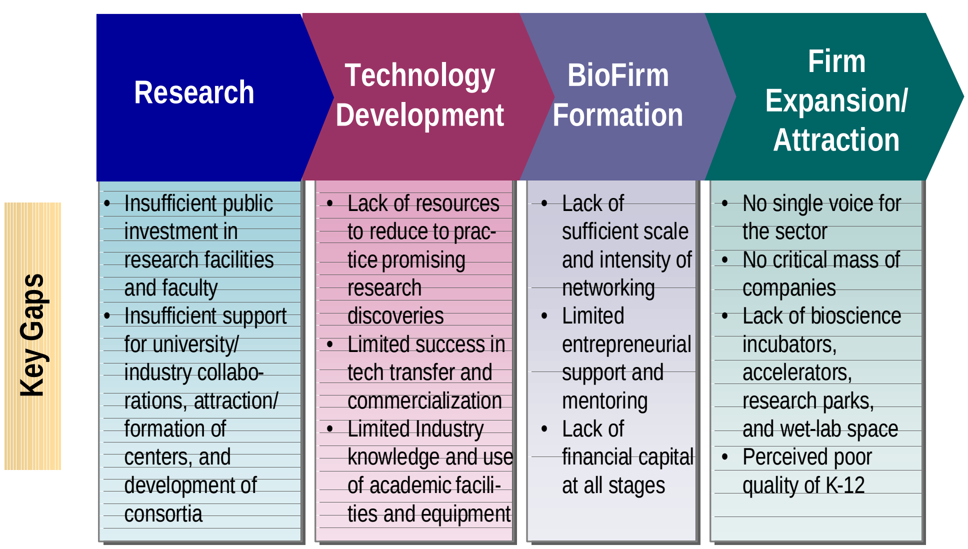
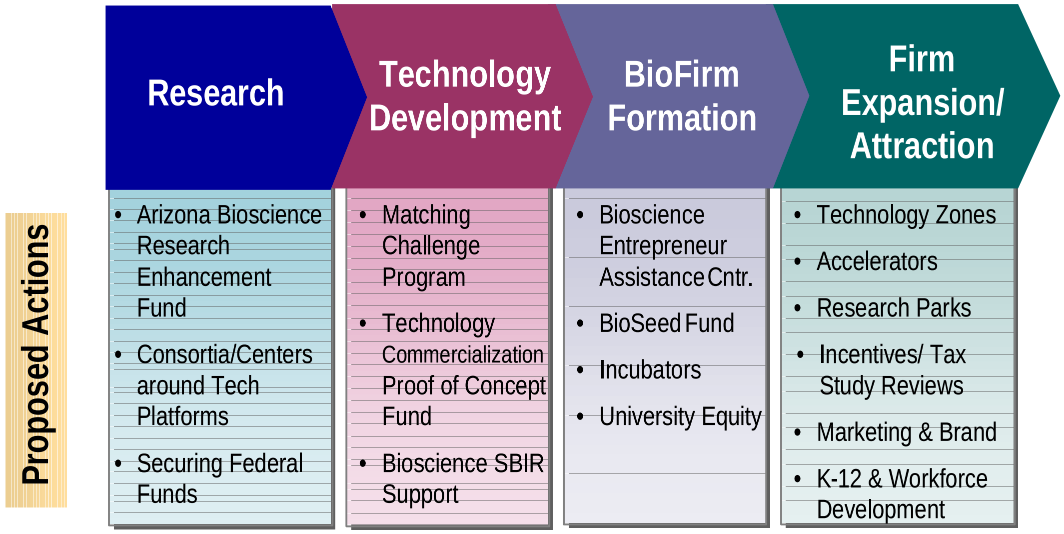


Figure ES-5. Proposed Actions to Address Key Gaps Along the Life Science Development Continuum



Mobilizing Private and Public Leadership and Increasing Knowledge and Understanding of the Biosciences

The state's current efforts remain fragmented and disorganized in the biosciences. Industry leadership is divided among multiple organizations. Connectivity with higher education varies among industry segments. Great differences exist among the state's public universities in their management of intellectual property and its commercialization. While entrepreneurship in general is strong in the state, it has not been strong among bioscience-talented individuals.

Because of the need to sustain efforts to build a regional or state bioscience base over the long term, committed leaders, i.e., champions, must step forward in the state to help lead efforts to address barriers and gaps, secure research and other funds, and market and sell Arizona as a state where biosciences is good business**.** Building a committed strategic leadership alliance of private, public, philanthropic, and capital sources will be needed to ensure that this Roadmap and the strategies proposed in it are implemented.

Strategies and Actions

Four strategies are proposed to develop Arizona's bioscience research base and build a critical mass of bioscience companies.

- **Strategy One***:* *Build the state's research infrastructure of outstanding talent and modern facilities and equipment around selective technology platforms and core competencies.*
- **Strategy Two:** *Build a critical mass of bioscience firms by increasing the birthrate and reducing the death rate of Arizona's bioscience firms and encouraging the commercialization of research discoveries.*
- **Strategy Three:** *Offer a business climate and environment that supports, sustains, and encourages the growth of bioscience enterprises, small and large, to start, expand, and remain in Arizona.*

- **Strategy Four:** *Encourage the state's citizens to become a more informed citizenry in the biosciences and encourage young people to explore and pursue scientific and technical careers.*

These four strategies, and the proposed 19 actions they encompass, are outlined in Table ES-5. Implementation of these strategies and actions is anticipated over a five- to 10-year period. *Immediate* actions should be undertaken as soon as possible, *short-term* priorities should be undertaken in the one- to three-year period, *mid-term* priorities should be implemented in the three- to five-year time period, and *long-term* in the five- to 10-year time period.

Table ES-5. Summary of Proposed Strategies and Actions for the Roadmap Alliance

Strategy	Action	Priority
Strategy One: Build the state's research infrastructure of outstanding talent and modern facilities and equipment around selective technology platforms and core competencies.	Establish a statewide fund (the Arizona Bioscience Research Enhancement Fund) to enhance bioscience research	Immediate
	Stimulate research collaboration among universities/hospitals/other research organizations by creating consortia, centers, and institutes in bioscience platform areas and related engineering/information technology areas	Immediate to Mid-term
	Establish a Bioscience Matching Challenge Program to connect industry and researchers and to encourage university-industry partnerships	Immediate
	Increase help to entrepreneurs to secure federal SBIR/STTR funds	Short-term
	Secure federal investments to build Arizona's bioscience capacity, including working with the state's Congressional Delegation	Immediate
	Adequately fund Arizona's public higher education system overall; and use bond financing to meet higher education's capital needs for research, laboratory, and education facilities and equipment	Short-term
	Address the need to attract top graduate students to research opportunities in Arizona	Short-term
Strategy Two: Build a critical mass of bioscience firms by increasing the birthrate and reducing the death rate of Arizona's bioscience firms and encouraging the commercialization of research discoveries.	Provide in-depth, comprehensive, entrepreneurial assistance support to start-up and emerging bioscience companies	Immediate
	Support prototype development and proof-of-concept activities from research to commercialization	Short-term
	Invest at earliest stages of firm formation through an Arizona BioSeed Fund	Short-term
	Provide wet-lab space through support of bioscience accelerators/incubators/wet-lab space in and around research parks	Short-term
	Provide a mechanism for Arizona universities to take equity in start-up companies	Immediate

Table ES-5. Summary of Proposed Strategies and Actions for the Roadmap Alliance (continued)

Strategy	Action	Priority
Strategy Three: Offer a business climate and environment that supports, sustains, and encourages the growth of bioscience enterprises, small and large, to start, expand, and remain in Arizona.	Revise state/local economic development programs and the state's tax code to support the growth, expansion, and selective recruitment of bioscience firms	Short-term
	Establish Technology Zones around existing and proposed concentrations of bioscience and other technology industries	Short-term
	Form regional bioscience technology councils as separate organizations or as part of a broader regional technology council	Short-term
	Initiate a statewide image, marketing, and business development effort to market Arizona as a location for bioscience firms	Long-term
Strategy Four: Encourage the state's citizens to become a more informed citizenry in the biosciences and encourage young people to explore and pursue scientific and technical careers.	Create capacity to understand and address health policy issues from review boards and central data banks to ethics and public policy reviews	Long-term
	Address future talent pool by making improvements in science and math in K–12 through graduate education	Long-term
	Encourage talent to remain in the state by expanding co-op and internship programs	Long-term

ROADMAP ALLIANCE IMPLEMENTATION

The bioscience sector is an important and growing part of the Arizona economy. Without directed actions to sustain and renew expansion in the biosciences, current growth rates are unlikely to be maintained by internal industry dynamics and momentum alone. Furthermore, even if present growth rates were to continue unabated, the time required for the state to reach national prominence in the biosciences is measured in decades. If Arizona is to achieve its vision for the biosciences, it must aggressively implement the strategies and actions outlined in this report. However, with limited resources, it is important to set priorities. The following section identifies critical actions that must be taken to develop Arizona's bioscience sector.

Critical Actions

The successful implementation of the following eight activities will ultimately determine whether Arizona can competitively position itself in the biosciences:

- Form the **Arizona Bioscience Research Alliance** to serve as steward for this Roadmap's implementation, as well as possible direct operational involvement in those action items that otherwise cannot be initiated without the Alliance's leadership role.
- Establish the **Arizona Bioscience Research Enhancement Fund** to provide the necessary investments in higher education research and education (e.g., endowed chairs, recruitment packages, laboratories, instruments, and faculty) for its universities to secure world-class

stature in selective platform areas in collaboration with other medical, health, industry, and nonprofit research organizations.

- Form, from this Arizona Bioscience Research Enhancement Fund and federal funds, **consortia/centers in the key technology platform areas** identified in this report—neurological sciences, cancer therapeutics, and bioengineering.
- **Pursue, in concert with Arizona's Congressional Delegation, federal funds and investments** to further build the state's research enterprise.
- Establish the **Arizona BioSeed Fund** to offer an indigenous source of pre-seed and seed investments necessary to build a critical mass of homegrown bioscience firms.
- Establish the **Arizona Technology Commercialization Prototype Development Fund** to "mine" research in Arizona's research organizations to develop products and processes used by existing companies or around which new firms can be created.
- Establish the **Arizona Entrepreneurial Assistance Center** to provide in-depth mentoring and support from seasoned entrepreneurial managers (also responsible for managing the BioSeed Fund and Technology Commercialization Prototype Development Fund).
- **Provide adequate funding, including general obligation state bond financing, for higher education research facilities and laboratories.**

The biosciences address a concern of all the state's residents—access to quality health care in an environment in which the latest treatments, diagnostics, and prevention methods are practiced daily by medical and health care personnel who are outstanding clinicians, researchers, and practitioners. In addition, the biosciences provide a way to build a stronger, more stable, and diversified Arizona economy, offering quality, well-paying jobs from technician to researcher.

Immediate Work Plan Priorities

Immediate work plan priorities are those steps the private and public sectors in Arizona should undertake in the first 12 months of strategy implementation. Several critical priorities need to be implemented right away, while others will need to be planned and allocated funds before they can become fully operational.

The following actions should be undertaken in the first year of implementing the Roadmap Alliance:

- Form the Arizona Bioscience Research Alliance to serve as steward for this Roadmap's implementation.
- Begin the process of encouraging gubernatorial and legislative support for the Arizona Bioscience Research Enhancement Fund, possibly by administratively using state general obligation bonding authority to fund facilities, labs, and recruitment packages for bioscience development in the key technology platform areas.
- Work with the philanthropic sector, state government, and higher education institutions to develop strategic business frameworks and investment plans for each technology platform area.
- Discuss and develop a concept plan and begin to build gubernatorial and legislative support for the formation of an Arizona Bioscience Matching Challenge Program.

- Prepare an annual list and a multiyear strategy of key bioscience projects and investments to submit to Arizona's Congressional Delegation.
- Resolve the approach necessary to enable the state's public research universities to take an equity participation in licenses.
- Develop a prospectus for the entrepreneurial assistance center.
- Begin discussions with in-state angel and other wealthy investors, the state's private and public pension and venture funds, and leaders in industry and higher education to secure capital commitments for the Arizona BioSeed Fund.
- Develop stronger regional bioscience councils, either stand-alone or part of a broader technology council, and increase the scale of networking activities for the bioscience industry.
- Use existing state and regional promotion and marketing funds to focus on making Arizona a more recognized center in the biosciences and develop Arizona's "brand name" in the biosciences.
- Begin planning for an expanded co-op and internship program**.**

Organization and Structure for Implementation of the Roadmap Alliance

State science and technology initiatives are most effective when they are executed on a bipartisan basis, with strong executive and legislative branch support, involvement, and cooperation. States such as Pennsylvania, New York, Georgia, Maine, Maryland, and North Carolina have been successful with their science and technology investments because their efforts have been broad based, they have mobilized private sector champions behind them, and their initiatives have become institutionalized into the state and regional fabric of both economic development and higher education.

This Bioscience Roadmap proposes a set of strategies and actions that involve many private and public sector organizations. Directing this Bioscience Roadmap of and serving as steward are both sensitive and critically important to the success of the entire set of strategies. Therefore, Battelle suggests that the most appropriate approach is to form the Arizona Bioscience Research Alliance (ABRA) to both coordinate efforts and, where necessary and appropriate, directly operate programs such as the Bioscience Research Enhancement Fund, the Bioscience Matching Challenge Program, and/or the Entrepreneurial Assistance Center. One or more of these programs might be more appropriately managed by a newly created nonprofit or for-profit, such as the Entrepreneurial Assistance Center, which also would co-manage the BioSeed Fund and the Technology Commercialization Prototype Development Fund.

It is Battelle's recommendation that ABRA should be legally organized as a private, nonprofit corporation with a majority of its board from industry.

ABRA also is expected to work closely with the Arizona Department of Commerce, the Arizona Board of Regents, and the state's three public research universities and their leadership to ensure that related science and technology programs are linked to its efforts. ABRA will focus on both research excellence and technology commercialization around the technology platforms laid out earlier.

Overall, Arizona’s bioscience delivery system will be composed of the following key components:

- The Arizona Bioscience Research Alliance
- Entrepreneurial Assistance Center, co-managing the BioSeed Fund and Prototype Development Fund
- Technology-led trade and civic organizations in each region, working together on statewide needs and issues
- Arizona’s higher education anchors, including research universities, comprehensive universities, and community colleges.

Arizona cannot stand still and remain economically viable while other states make key investments in their future around the biosciences. The key to the success of this Roadmap is sound execution that requires talent, commitment, and perseverance. Strategies can be successful only if implementation is achieved.

Measures of Success

Performance measures and goals are proposed below, with actual monitoring undertaken on an ongoing basis through the Arizona Bioscience Research Alliance to determine to what degree performance objectives are being accomplished. Key measures to monitor progress might include the following:

- Increase in bioscience R&D funding to Arizona research institutions at a rate equal to or greater than the historical growth rate of the top 10 states over the next five years.
- An increase in NIH funding from $118 million to $214 million by 2007.
- Start-up and survival rates of Arizona bioscience firms exceeding the average rates for benchmark states as identified in this Roadmap.
- An increase in the concentration rate and thus degree of specialization relative to the nation in at least two industry segments (LQ >1.20) by 2007.
- Leveraging of federal and other dollars at least three times for every $1 in Arizona support.
- Dollars of bioscience venture investments to Arizona-based firms to total at least $100 million in 2007.
- Arizona university-related start-ups/revenue dollars to exceed the top quartile ratio of all U.S. universities by 2007.
- Implementation progress on the actions laid out in this Roadmap—at least 70 percent with substantial action after three years, and 90 percent within five years.

In addition to these outcome and impact measures, Arizona should update this Roadmap every three to five years to adjust to changing economic conditions.

Resources Required

Table ES-6 shows, for each action, the priority of the action and the annual and one-time costs. The successful effort to raise funds for TGen illustrates the level of stakeholder involvement and support across a number of private and public organizations that will be needed to successfully implement this Roadmap.

Table ES-6. Arizona Roadmap Resource Requirements

Action	Priority	Annual Cost	One-time Costs	Leverage Ratio
Arizona Bioscience Research Alliance	Immediate	$400,000–$500,000	0	N/A
AZ Bioscience Research Enhancement Fund	Immediate		$42 million/year for 8 years	1:9
Research collaborations, consortia, centers, and institutes	Two Immediate initiatives (TGen/IGC and ARC) Third effort years 4–6 or sooner	$10 million/year in non-federal operating support	$400 million for capital projects around platforms TGen/IGC– $90 million	1:9
Bioscience Matching Challenge Program	Immediate to short-term	Initially $750,000 rising to $6 million/ year by year ten	0	1:3
Bioscience SBIR Support Program	Short-term	$400–$600,000	0	1:4
Seek federal funding with Congressional Delegation	Immediate		Goal of $170 million or more over 10 years in federal funds	1:150
Adequately fund higher education	Short-term	Use bonding authority to finance capital improvement projects		N/A
Attract graduate students	Short-term	$1.8 million/year	0	1:3
AZ Bioscience Entrepreneur Assistance Center	Immediate	$400–$600,000	0	N/A
Bioscience Technology Commercialization Prototype Development Fund	Short-term	0	$12–$15 million every five years	1:5

Table E-6. Arizona Roadmap Resource Requirements (continued)

Action	Priority	Annual Cost	One-time Costs	Leverage Ratio
AZ BioSeed Fund	Short-term	0	Up to $70 million in private and other support	1:9
Incubators/accelerators and research parks	Short-term	Operating support for incubator of $150–$250,000 annually for first 18–36 months for three facilities	$50-$70 million for three incubators/ accelerators $40–$50 million for research park and related infrastructure	1:5
Mechanism to allow universities to hold equity	Immediate	No additional costs but source of additional revenues		N/A
Comprehensive review of economic development and tax policy	Short-term	0	$500–$750,000	N/A
Technology zones	Short-term	To be determined	To be determined	N/A
Regional bioscience councils	Short-term	$250,000/ year each for two councils	0	All private
Image, marketing, and business development	Long-term	Redirect existing resources	0	N/A
Capacity to understand and address health policy issues	Long-term	$3 million a year	0	From philanthropic and other sources
K-12 education • Curriculum development • Support for science teachers • Loan forgiveness programs	Long-term	 $1–$2 million $5–$25 million	$250–$500,000	1:2
Expanded internships and co-op programs	Long-term	$200–$500,000 logistics support leveraged with significant private support	0	1:3

Economic Impact Analysis

The Arizona Bioscience Roadmap lays out a list of strategic investments across the entire continuum of bioscience development, from basic research to firm formation and attraction. This multiyear investment program, stretching over at least a decade or more, will provide the types of investments at a sufficient scale to achieve a critical mass of research around key technology platforms and, ultimately, result in a critical mass of bioscience firms populating Arizona by 2012.

Battelle's economic impact analysis indicates that the investments recommended in this Roadmap can result in the following impacts:

- **Critical Mass of Research Support.** The State of Arizona can reach a level of NIH funding equal to the historic growth rates of the top 10 states in NIH funding by 2007, resulting in $274 million of annual federal NIH funding. In addition, the investments made in research facilities, faculty, and instrumentation will attract additional funding equal to three times their costs within the next 10 years.
- **Critical Mass of Businesses and Jobs.** Arizona's non-hospital bioscience industry will grow by an additional 120 firms and create an additional 12,900 jobs by 2012. This critical mass of bioscience firms will have a multiplier effect on other business service and supplier sectors of the economy, accounting for an estimated 17,000 additional jobs in all sectors of Arizona's economy.
- **Leveraged Investments.** For specific investments in the Bioscience Roadmap designed to leverage other financial support, every $1 that Arizona's private and public sectors provide is estimated to leverage $6.26 in other investments.

CONCLUSION

Arizona must play "catch up" to other states if it is to become a major southwestern state in the biosciences. The first effort of success—the attraction of TGen and IGC to Arizona—will need to be replicated in other technology platform areas identified in this Roadmap. Focusing on a few platforms, rather than trying to spread limited resources across multiple areas, is one effective way for Arizona to indeed catch up. Technology commercialization must be concurrently addressed if the state is to build a critical mass of bioscience firms and to apply research to patient care and quality health care delivery.

This Roadmap lays out a comprehensive approach to accomplish this plan, with details in the full report and highlights in this executive summary. This Roadmap proposes a bioscience agenda based on private sector, market-driven needs, and recommends actions and their implementation around filling private sector gaps through industry-led private-public partnerships.

Arizona's current situation is not unique. Other states and regions once behind in the development of their bioscience sectors (including San Diego, California; Montgomery County, Maryland; Birmingham, Alabama; and Portland, Oregon) have either successfully positioned themselves as a leading bioscience region or are focusing their strategic investments to carve out a particular market niche for the future.

Introduction

In 10 to 15 years, Arizona will be known for its research strengths in key areas of the biosciences and home to a growing number of bioscience companies. Quality health care will be offered to the state's citizens based on translating research into treatment, prevention, and diagnostics. The bioscience sector will provide high-wage opportunities for Arizona graduates and will attract skilled technical workers to locate in Arizona. The biosciences will be a significant element of Arizona's knowledge economy.

This is the vision of Arizona's public and private leaders who have made a commitment, as evidenced in the support provided to attract the International Genomics Consortium (IGC) and the Translational Genomics Research Institute (TGen), to develop Arizona's bioscience base. But, why should Arizona focus scarce resources on the bioscience sector and, if it does, is it likely to succeed in developing a critical mass of bioscience companies?

WHY FOCUS ON THE BIOSCIENCES?

By virtue of its size and diversity, the bioscience sector offers the opportunity to create new firms, high-wage jobs, and income for Arizona citizens. The bioscience sector of the economy is large, fast growing, diverse, and crosscutting, involving a wide range of manufacturing, service, and research activities. Industries involved in the biosciences range from pharmaceutical development to agricultural production, from medical device assembly to biological research and testing, from understanding and protecting biological and environmental systems to providing healthcare services. Moreover, the experience of leading bioscience states coupled with the recent surge of interest in the field suggests great potential for rapid and extensive growth of new bioscience firms. Arizona has the capacity to engage in several industry segments and develop strong specializations in niche markets, employing many residents in well-paying jobs and generating significant income for the state and its citizens.

The bioscience sector can build on Arizona's existing strengths in electronics, optics, and advanced manufacturing and contribute to the growth of these sectors as well. The diversity of the bioscience sector places it at the center of the technology economy, serving as a focal point for the continuing convergence of technologies from information and computing to advanced manufacturing. Developing the biosciences in Arizona can build from existing economic strengths of the state—such as electronics, optics, and plastics—and offer opportunities for bringing together competencies to establish depth as well as breadth of expertise. Applications and spin-offs from the

Structural Diversity Rankings

Utah	1
Georgia	6
California	10
North Carolina	11
Massachusetts	13
Texas	19
Arizona	**21**
Oregon	27
Oklahoma	30
Washington	43

Source: *Development Report Card for the States 2001*, Corporation for Enterprise Development.

biosciences may help boost other technology-based industries in the state, including advanced manufacturing and information technologies.

The bioscience sector can bring stability to Arizona’s economy. As an economic driver, the bioscience sector is diverse enough to ensure relative stability. Because the field extends into a variety of activities spread across the economic spectrum, developing the biosciences provides insulation against the ups and downs of business cycles. Arizona’s traditional economic strengths in hospitality and tourism, construction, and real estate provide limited protection. Arizona’s economy currently is less structurally diverse than most of its competitors and the leading bioscience states, for instance, as measured by the *Development Report Card* of the Corporation for Enterprise Development, and thus is less likely to weather economic downturns successfully.

The bioscience sector will offer employment opportunities for Arizona residents across a broad range of occupations. The biosciences offer abundant employment opportunities over the entire range of education and experience levels, from research scientists and medical doctors to technicians, laboratory researchers, and manufacturing workers. Contrary to public perceptions, the largest share of employment in the biosciences nationally consists of production and technician positions—more than 50 percent of employment in medical device industries, more than 40 percent of pharmaceutical employment, and more than 30 percent of workers within the organic and agricultural chemicals industries.[3] Even in hospitals, nursing and healthcare support occupations constitute the largest employment segment.

Average Employee Earnings

Drugs	**$89,608**
Organic chemicals	**70,273**
Agricultural chemicals	**61,423**
Aerospace	60,300
Industrial machinery	56,800
Motor vehicles	56,500
Medical devices	**52,957**
Metals	41,300
Construction	37,600
Entire private sector	36,300
Rubber & plastics	36,100
Hospitals & laboratories	**36,000***
Hospitality & recreation	21,500*

* Underestimates service industry earnings due to prevalence of part-time employment.
Note: Dollar amounts are real 2001 dollars.
Source: Covered Employment and Wages (ES-202), Bureau of Labor Statistics, 2000.

The biosciences will create wealth for Arizona residents. The jobs created and sustained by the biosciences tend to be high paying and relatively secure, helping to build and retain local wealth and prosperity. Drug and chemical jobs pay salaries and wages well above the average even for other technology fields, while medical devices is on a par with other manufacturing industries. Even hospitals and laboratories, though engaging many part-time workers, support jobs spanning the range of the pay scale.

In summary, Arizona’s elderly and growing minority population bases will demand quality health care, which itself will benefit from the fruits of medical research and the availability of talented health workers—from technicians to postdoctoral fellows. Growth in the medical device, agriculture, and other biotechnology sectors offers job opportunities for these graduates so they may remain in Arizona and become employed in well-paying jobs.

The biosciences, while not the only possible growth industry, present advantages that strongly suggest that the state make the investments that will be needed to make the biosciences an

[3] Calculated from Occupational Employment Statistics, Bureau of Labor Statistics, 2000.

essential component of Arizona's economy. But, is it likely that Arizona can succeed in growing this sector?

CAN ARIZONA SUCCEED IN DEVELOPING ITS BIOSCIENCE SECTOR?

An initial review of Arizona's bioscience base shows that Arizona has some key assets on which to build a strong bioscience sector.

- Arizona possesses an economic base in the biosciences that is small but rapidly expanding, outpacing national growth trends.
- Arizona has a base of research institutions and medical centers on which to build that includes the Arizona Cancer Center and the Institute for Biomedical Science and Biotechnology at the University of Arizona (UA), the Arizona Biomedical Institute at Arizona State University (ASU), the Keim Genetics Laboratory at Northern Arizona University (NAU), and Barrows Neurological Institute.
- TGen, IGC, and ASU, NAU, and UA Centers and Institutes will become anchors on which to continue to build a bioscience cluster.
- The leadership of Arizona's universities is committed to building its bioscience research bases and aggressively promoting technology transfer and commercialization.
- In recent decades, Arizona has established itself as a major player in basic research primarily focused on the physical sciences and ecology, areas that may complement and assist the state in building its bioscience base in areas such as imaging, optics, and biomedical engineering.
- Arizona has taken significant and meaningful steps to augment its state support for bioscience research with its health research fund, Proposition 301 funding, and the approval to dedicate new tobacco tax revenues in part to additional research.

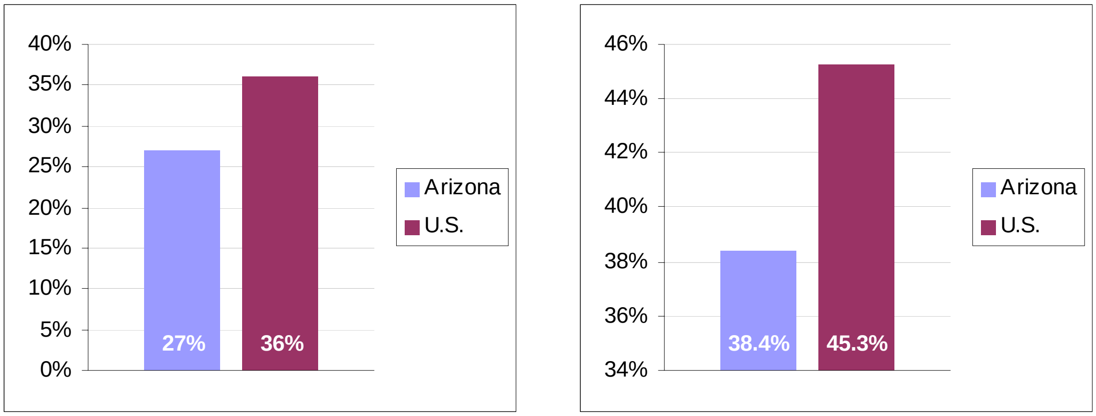
On the other hand, Arizona faces key challenges in trying to develop the bioscience sector.

- First, Arizona is playing catch-up in terms of bioscience research, the key driver of bioscience development. Despite a sizeable base, Arizona's bioscience research efforts have been lagging the nation. Arizona's national ranking in university-based bioscience research funding compiled by the National Science Foundation (NSF) for fiscal year (FY) 2000 is 27th in the nation (Figure 1).[4] More importantly, total bioscience research funding grew only 27 percent in Arizona from 1996 to 2000, compared with 36 percent for the nation.[5] National Institutes of Health (NIH) funding—the gold standard of biomedical research funding—is also lagging. For FY 2001, Arizona received $117 million in research funding from the NIH, placing the state 27th in the nation.[6] Growth in NIH funding from FY 1997 to 2001 stood at 38.4 percent in Arizona, compared with 45.3 percent for the nation.[7]

---

[4] NSF, Academic R&D Expenditures, with Battelle calculations for state rankings.
[5] NSF, Academic R&D Expenditures, with Battelle calculations for percentage changes in Arizona and the nation.
[6] NIH, Office of Extramural Research, Historical Funding data.
[7] NIH, Historical Funding, with Battelle calculations for percentage changes in Arizona and the United States.

Figure 1. Arizona is Lagging in Bioscience Research Growth in Late 1990s



University Bioscience Research Growth from 1996 to 2000

NIH Bioscience Research Growth from FY 1997 to 2001

- Second, Arizona lacks a critical mass of bioscience firms and the business infrastructure required to support them. Venture capital is a critical need in Arizona. The state has few economic development assistance programs to attract, retain, and grow bioscience firms. In contrast, other states offer a comprehensive array of programs and services to support the creation and growth of technology businesses. In light of these challenges, how realistic is it to expect to see results from the state's efforts to develop the biosciences and during what time frame?

Bioscience Success Stories

Examining the accomplishments of other states and regions illustrates their significant investments in bioscience-based economic development initiatives.

The Georgia Bioscience Success Story. In the mid- to late-1980s in response to Georgia's unsuccessful bid to win the competition for the location of the Microelectronics and Computer Consortium (MCC), which located in Austin, the State of Georgia determined that it would be necessary to create in Georgia a capacity for fundamental research and development (R&D) to attract and grow new science and technology-based industries. In 1990, a consortium of Georgia business leaders conceived and founded the Georgia Research Alliance (GRA). GRA was designed to bring together business, government, and higher education to develop research capabilities and assist technology-based industry.

Since 1991, the State of Georgia has invested $312 million into GRA-directed programs. These funds have been used to construct state-of-the art research facilities and laboratories and to attract Eminent Scholars to Georgia universities. Much of these funds have been invested to develop the bioscience sector. During the last 10 years, R&D expenditures in Georgia have doubled, increasing from $400 million annually to $800 million. From FY 1995 to FY 1999, total bioscience research in Georgia jumped by $96 million , reaching $430 million. Total Georgia NIH awards almost doubled between FY 1997 and 2000. The state attributes much of this increase to its GRA investments. Similar investments by Arizona could be expected to lead to similar results.

While Georgia needed to build its research base, other states have worked to develop their commercial bioscience bases.

The Maryland Bioscience Success Story. Ten years ago, Maryland faced challenges similar to those Arizona is facing today. While Maryland had a significant life science research base with the presence of NIH, Johns Hopkins University, and the University of Maryland, the state was struggling to leverage the presence of that research base and to move beyond a base of NIH supplier and support companies to develop more product-driven companies.

The region lacked a bioscience business infrastructure, and venture investment dollars were scare. Maryland was able to overcome these barriers by undertaking a comprehensive set of initiatives that address venture capital, business incubation, commercialization, workforce development, and tax and regulatory issues. Maryland built a critical mass of companies by nurturing entrepreneurs and start-up bioscience companies and facilitating networking among them. In 1991, Maryland adopted a state strategy to grow its commercial bioscience sector. At that time, Maryland had 53 biotechnology companies employing 3,627 people. Ten years later, in 2001, Maryland had 258 companies, 39 of which are public, with total employment of almost 16,000.

The San Diego Bioscience Success Story. Lastly and even closer to home is San Diego. As late as the mid- to late-1980s, San Diego was known more for its large aerospace and defense contractors than for the life sciences. Nor was it considered an entrepreneurial hot spot. Despite the fact that San Diego was home to Scripps Research Institute, the Salk Institute, and the University of California at San Diego (UCSD), which had been a strong bioscience research center as early as the early 1970s, San Diego had no significant bioscience sector. Quality of life was high, and yet, the critical spark was lacking.

San Diego, like Atlanta, Georgia, was jarred by its failure to win the national competition for MCC (1985) and SEMATECH (1988). Then, with the collapse of the Soviet Union in 1989, San Diego's major defense employers dramatically downsized or closed shop entirely. In 1985, under the leadership of Richard Atkinson, then Chancellor of UCSD, a new entity, CONNECT, was created to support the development of technology-based companies in San Diego.

CONNECT is a mentoring, networking, and advocacy organization operated by UCSD. Initially, CONNECT provided considerable direct instructional support to companies that had already spun off from San Diego's anchor institutions. Then, as the first generation of entrepreneurially trained managers moved on from their initial positions, CONNECT helped a second wave of start-ups emerge, thrive, and develop a community of interest. The organization also provided a convenient vehicle through which the well-developed venture-capital community of the Bay Area and Silicon Valley could sift through opportunities and generate deal flow that made it worth their while to spend time and effort in San Diego and ultimately open branch offices. Finally, and perhaps most importantly, CONNECT sent the message that UCSD was supportive of spin-offs and wanted its faculty to play a role either directly as entrepreneurs or indirectly through research collaboration.

Due to the presence of world-class bioscience research insertions such as the Scripps Research Institute, the Salk Institute, and the UCSD, in partnership with the entrepreneurial support system fostered by such organizations as CONNECT, within the first eight years of the 1990s, San Diego realized unprecedented employment growth in the bioscience industry. In 1990, slightly more than 11,000 people were employed in the biotechnology and pharmaceutical sectors. By 1998, that number had increased to almost 23,000. Interesting to note, in 1990, San Diego was home to 60 biotechnology companies—the same number that Tucson has today.

WHAT WILL IT TAKE TO DEVELOP THE BIOSCIENCES IN ARIZONA?

Developing the biosciences in Arizona will require

- ***Patience and a long-term commitment.*** One lesson from every successful technology community is that success takes time. Silicon Valley and Route 128 trace their origins in electronics to the 1950s and in the life sciences to the 1970s. Research Triangle Park represents a 50-year strategy that has only recently found its footing in the life sciences and is still working to develop full capability in the entrepreneurial sector. In contrast, Maryland has emerged as a major bioscience center in 12 to 14 years. While this may indicate that the time required to become a leading life science center can be shortened, it must be recognized that such development cannot be accomplished in a year or two. It requires a long-term effort, measured in a decade or more.
- ***Champions.*** To be successful, the development of the biosciences in Arizona must have champions—leaders with the ability to bring all of the relevant players to the table and the means to see that the strategic recommendations are implemented.
- ***Strategic focus.*** Successful regions have recognized that they have neither the capacity nor the assets to excel in all areas of technology. Instead, they have examined their comparative advantages, found both within their industrial and research bases, and focused their investments on competitive niches in which they can and do excel.
- ***Strong public/private partnerships.*** Raising the level of research activities is a cornerstone to becoming and sustaining a robust life science cluster. But, it takes more than simply research stature. It requires the capability to engage industry, directly or indirectly, to convert this intellectual knowledge into economic activity. To do so requires one or more of a region's research anchors committed to engage with and help build and sustain a life science community locally. To succeed, a region must have a university or other form of research anchor that has already made this commitment or a state government committed to using discretionary R&D funding to induce its public and private research universities to undertake that commitment.
- ***Active state and local government support.*** It is widely recognized that the principal driver of basic research in the United States is the federal government. Therefore, what is the role of state, regional, and local government? The state and local role is to ensure that the infrastructure, such as research facilities, faculty, and physical infrastructure, required to leverage federal dollars is in place. Their economic development role is to help find solutions to fill market gaps in ways that support, spur, link, and leverage ongoing private investments. These economic development efforts include focusing on public-supported research universities; addressing the future talent pool through education and workforce programs; and ensuring a high quality of life, including a sound tax and regulatory climate. A related but important role of state government is improving the quality and access to health

care within its borders, including research that translates into health care practice and treatment.

- ***Willingness on the part of the state's research institutions to partner.*** In today's competitive field of bioscience, no one research entity will be able to "go it alone" effectively. For real success to occur, research institutions will need to partner to leverage resources, funding, and scarce knowledge assets.

The Milken Institute recently found that

> *Where clusters of existing technologies expand and emerging science-based technologies form will be critical factors in determining economic winners and losers in the first half of the 21st century. As economic activity is based more on intangible assets, those states with vibrant technology clusters will experience superior economic growth. It is imperative for state and local development officials and business leaders to promote high-tech expansion and cluster formation.*[8]

The remaining sections of this report lay out a vision for Arizona's bioscience sector and an integrated set of comprehensive strategies and actions to enable Arizona to achieve its vision for the biosciences, allowing the state to be an "economic winner" in the 21st century.

[8] Milken Institute, *State Technology and Science Index: Comparing and Contrasting California.* September 2002, p 5.

An Economic Analysis of the Biosciences in Arizona

During the past 15 years, the U.S. bioscience sector has developed into one of the fastest growing and most dynamic and productive aspects of the economy. The successful completion of the Human Genome Project introduced a new era of innovation, generating new or replenished areas of research and application ranging from immunology and molecular biology to genomics, proteomics, and bioinformatics. Even in the current environment of ongoing and largely unpredictable international conflict, renewed attention has focused on the biosciences, with regard to both biological warfare and bioterrorism and as a primary strength maintaining the economic health of the United States and the rest of the developed world.

The State of Arizona has the opportunity to develop the emergence of its current bioscience sector into a broad and durable economic strength, positioning Arizona as a leading southwestern state in selective bioscience sectors. This economic analysis explores the current position and contributions of the bioscience sector to the Arizona economy, as well as prospects for future expansion and development. Its purpose is to provide a thorough economic base for subsequent strategy consideration by evaluating the Arizona bioscience industry with regard to economic performance and potential. By identifying strengths and weaknesses at both the aggregate and industry-specific levels of detail, the stage will be set for economic and policy strategies to propel the future of the biosciences in Arizona.

METHODOLOGY

Efforts to categorize the biosciences are often hampered by the unusual breadth and convergence of the field, as well as the rapid pace of redefinition as the bioscience industry continues to diversify and develop. For the purposes of this analysis, the term "biosciences" refers to a relatively broad swath of biological and life science technology-related activity organized into five major categories: drugs, organic and agricultural chemicals, medical devices and instruments, hospitals and laboratories, and bioscience research and testing.[9]

[9] The definition used in this analysis was developed to examine the particular characteristics of the Arizona bioscience sector. Whereas previous studies have concentrated upon two or three of the most visible bioscience industry subsectors, this analysis seeks to incorporate other bioscience industry groups that may be important in the economic development of Arizona bioscience establishments, such as agricultural chemicals and medical research. Other regions or studies may construct differing definitions of the biosciences that are appropriate for describing and examining relevant local conditions or particular industry characteristics of interest.

Each of the five subsectors in turn comprises detailed industry segments identified at the four-, six-, or eight-digit Standard Industrial Classification (SIC) level (Table 1).[10]

This economic analysis uses establishment and employment data obtained from the *MarketPlace* survey, released on a quarterly basis by the Dun & Bradstreet Corporation, augmented with information from previous studies, local stakeholders, and publicly accessible Web sites.[11] Establishment-level data were obtained for the fourth quarters of 1995 and 2001.[12] Because the bioscience subsectors intentionally were defined to approach the range of bioscience activity in a broad fashion, the definition is highly suitable for comparisons between the state and national levels as well as between Arizona's major metropolitan regions.

The following narrative provides an overview of the data in an effort to provide a quantitative base from which subsequent strategy considerations can be formed.

Table 1. Biosciences Sectoral Definition, by SIC

	SIC
Drugs	
Medicinals and botanicals	2833
Pharmaceutical preparations	2834
Diagnostic substances	2835
Biological products except diagnostic	2836
Organic and Agricultural Chemicals	
Industrial organic chemicals, not elsewhere classified	2869
Nitrogenous fertilizers	2873
Phosphatic fertilizers	2874
Fertilizers, mixing only	2875
Agricultural chemicals, non-fertilizer	2879
Medical Device and Instrument Manufacturing	
Pharmaceutical machinery	3559-9922
Laboratory apparatus and furniture	3821
Analytical instruments	3826
Surgical and medical instruments	3841
Surgical appliances and supplies	3842
Dental equipment and supplies	3843
X-ray apparatus and tubes	3844
Electromedical equipment	3845
Hospitals and Laboratories	
General medical and surgical hospitals	8062
Psychiatric hospitals	8063
Specialty hospitals, except psychiatric	8069
Medical laboratories	8071
Dental laboratories	8072
Bioscience Research and Testing	
Biological research	8731-01
Commercial medical research	8731-9902
Noncommercial biological research organizations	8733-01
Food testing services	8734-9903
Seed testing laboratories	8734-9908
Veterinary testing	8734-9910

[10] Together, these subsectors cover the majority of bioscience activity in Arizona as well as the United States. Nevertheless, despite the breadth of the definition, enclaves of economic pursuit likely remain that are related to the biosciences but not included. In part, this reflects the inadequacy of the current industrial classification scheme to categorize bioscience activity; but, it is also symptomatic of the convergence precipitated by the diversity and spread of the bioscience sector. The North American Industry Classification System (NAICS), which has begun to replace the SIC system, does not repair this shortcoming, partly because of the inherent diversity of the biosciences, but also because the NAICS was devised prior to the worldwide explosion of interest and activity in the biosciences. Both the SIC systems and the NAICS were designed and delineated by the federal government, NAICS in cooperation with Canada and Mexico.

[11] Studies that have informed this analysis include: *Turning Point: New Choices for the Future*, Greater Phoenix Business Leadership Coalition, March 2002; *Industry Clusters in Southern Arizona, 2001 Status Report*, University of Arizona Office of Economic Development, March 2002; *Five Shoes Waiting to Drop on Arizona's Future*, Morrison Institute for Public Policy, Arizona State University, October 2001; *The Bio Industry in Arizona*, Collaborative Economics, June 2001; *Designing the Future: The Bioindustry in Arizona*, Barbara Morehouse, Ph.D., University of Arizona, April 1997.

[12] Release dates are the first day of the quarter; thus, a fourth-quarter release date is October 1. Throughout the rest of this analysis, the time periods are referenced by year only.

THE ARIZONA BIOSCIENCE SECTOR

Arizona Bioscience Sector Profile

- The 1,216 Arizona bioscience establishments employ nearly 72,000 workers.
- Between 1995 and 2001, the Arizona bioscience sector's employment increased 24.3 percent, compared with 7.0 percent national growth.
- The bioscience sector is, however, 28 percent less concentrated in Arizona than nationwide.

Arizona possesses an economic base in the biosciences that is small but rapidly expanding, outpacing national growth trends. As of 2001, approximately 1,200 Arizona bioscience establishments employed nearly 72,000 workers. In the six-year period since 1995, Arizona has added 262 bioscience establishments, an increase of 27.5 percent, just ahead of the national pace of 26.7 percent. Arizona's employment growth in the bioscience sector has well outpaced the rest of the nation, reaching 24.3 percent between 1995 and 2001, compared with 7.0 percent for the entire country (Table 2).

Table 2. Summary Data, Bioscience Sector (1995 and 2001)

Metric	Arizona	Phoenix	Tucson	Rest of Arizona	United States
Establishments, 1995	954	659	157	138	58,612
Establishments, 2001	1,216	759	225	232	74,252
Change in number of establishments, '95-'01	262	100	68	94	15,640
% Establishment growth, '95-'01	27.5	15.2	43.3	68.1	26.7
Employment, 1995	57,823	44,822	6,433	6,568	6,186,435
Employment, 2001	71,876	44,004	14,138	13,734	6,618,374
Change in employment, '95-'01	14,053	(818)	7,705	7,166	431,939
% Employment growth, '95-'01	24.3	(1.8)	119.8	109.1	7.0
Employees per establishment, 1995	60.6	68.0	41.0	47.6	105.5
Employees per establishment, 2001	59.1	58.0	62.8	59.2	89.1
% Share, private sector employment, 1995	3.89	4.10	3.15	3.52	5.58
% Share, private sector employment, 2001	3.35	2.97	4.36	4.03	4.64
Employment location quotient, 1995	0.70	0.73	0.56	0.63	n.a.
Employment location quotient, 2001	0.72	0.64	0.94	0.87	n.a.
Change in employment location quotient, '95-'01	0.02	(0.09)	0.37	0.24	n.a.
All private sector activity:					
% Establishment growth, '95-'01	28.9	24.1	25.5	49.7	23.4
% Employment growth, '95-'01	44.6	35.4	59.0	82.7	28.8
Employees per establishment, 2001	11.4	12.3	11.4	8.8	11.5
Population, 2001 (thousands)	5,307	3,384	863	1,061	284,797
% Population growth, '95-'01	23.2	27.1	14.4	19.0	8.4

Data sources: Battelle calculations from Dun & Bradstreet *MarketPlace* survey, U.S. Census Bureau.
Note: n.a. = not applicable.

However, Arizona is 28 percent less concentrated in the biosciences than the nation. Despite the recent growth in this sector, the biosciences constitute a smaller proportion of the private sector economy in Arizona than nationwide, with only one in 30 Arizonans working in the bioscience industry. Arizona currently possesses a bioscience location quotient of 0.72, up slightly from 0.70 in 1995.[13]

BIOSCIENCE SECTOR COMPONENTS AND SPECIALIZATIONS

Growth in the Arizona bioscience sector is widespread, with each of the five bioscience subsectors outpacing the nation in terms of employment increase, indicating the breadth of opportunity in the sector. As previously indicated, the biosciences can be organized into five subsectors: drugs, organic and agricultural chemicals, medical devices and instruments, hospitals and laboratories, and bioscience research and testing. Examining these five subsectors reveals that Arizona employment growth has exceeded the national pace in each of the five bioscience subsectors between 1995 and 2001, in several cases by a large margin. For instance, growth in organic and agricultural chemicals was 186.6 percent higher in Arizona than in the nation, and employment expansion in medical devices and instruments was 45.4 percent higher (Table 3). Excluding hospitals and laboratories, Arizona's bioscience sector posted a six-year employment gain of 79.4 percent, compared with 28.3 percent for the entire nation.

Table 3. Arizona Bioscience Subsector Concentrations and Growth Rates

Subsector	2001 Employment	Location Quotient	%-point Difference between AZ and U.S. Empl. Growth '95-'01
Hospitals & laboratories	62,775	0.78	16.0
Medical devices & instruments	4,141	0.60	45.4
Organic & agricultural chemicals	1,896	0.70	186.6
Drugs	1,601	0.23	2.6
Research & testing	1,463	0.59	39.6
BIOSCIENCE SECTOR	71,876	0.72	17.3

[13] Location quotients are a common measure of the concentration of a particular industry or industry sector in a region relative to a reference area. The location quotient consists of the ratio of the share of total regional employment that is in the particular industry and the share of total employment in the reference area that is in the particular industry:

$$\textit{Location Quotient} = \left(\frac{\text{regional industry employment}}{\text{regional total employment}}\right) \Big/ \left(\frac{\text{reference area industry employment}}{\text{reference area total employment}}\right)$$

A location quotient greater than 1.0 indicates that the region is relatively concentrated in the particular industry, whereas a location quotient less than 1.0 signifies relative under-representation. Throughout this report, location quotients are used to report regional and metropolitan industry concentrations relative to the United States. The minimum concentration threshold for declaring a regional specialization is a matter of judgment and varies somewhat in the relevant literature. In this analysis, regional specializations are defined by location quotients of 1.2 or greater.

However, Arizona is less concentrated in the biosciences in each of the five bioscience subsectors than the rest of the nation. As previously noted, Arizona is 28 percent less concentrated in the biosciences than the nation. In addition, none of the bioscience subsectors exhibits a location quotient larger than 0.78, illustrating that Arizona lags the national level of bioscience industry presence across all of the subsectors.

For comparison purposes, Table 4 displays location quotients for each industry subsector in each of the benchmarks. Similar to Arizona, three other benchmark states, Georgia, Oklahoma, and Oregon, currently do not have a relative specialization in any of the bioscience industry subsectors. North Carolina, Utah, and San Diego have specializations in drugs and pharmaceuticals; Texas has a specialization in organic chemicals; Colorado, Utah, and San Diego have specializations in medical devices and instruments; and Texas, Utah, and San Diego have specializations in research and testing, the subsector that includes what is commonly thought of as biotechnology.

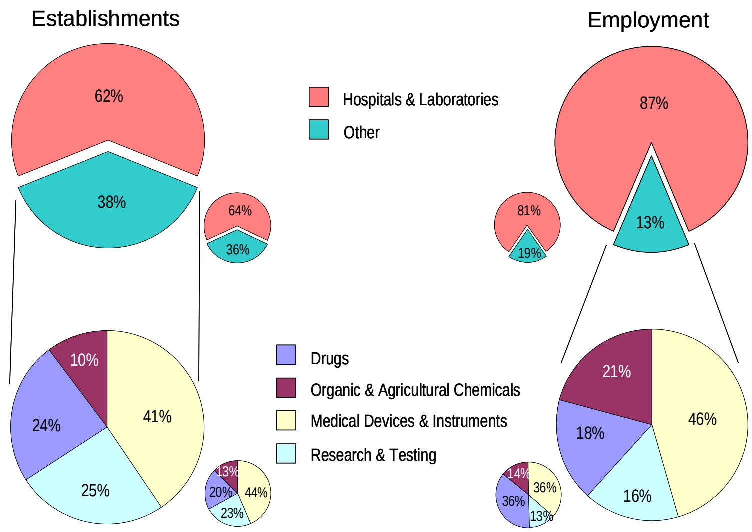
Table 4. Private Sector Bioscience Subsector Concentrations (Location Quotients) and Employment Growth (1995-2001)

	Drugs		Organic & Agricultural Chemicals		Medical Devices & Instruments		Research & Testing	
	LQ	% Emp Ch	LQ	% Emp Ch	LQ	% Emp Ch	LQ	% Emp Ch
Arizona	**0.23**	**47.4**	**0.70**	**199.5**	**0.60**	**62.0**	**0.59**	**83.6**
Colorado	0.40	46.7	0.17	72.3	*1.54*	-8.7	0.71	56.6
Georgia	0.21	69.7	0.98	70.3	0.34	-16.1	0.54	80.1
North Carolina	*1.45*	11.5	0.63	16.4	0.74	25.7	1.18	142.0
Oklahoma	0.21	85.5	0.49	12.8	0.33	22.4	0.39	-3.0
Oregon	0.21	110.8	0.21	-19.9	0.64	20.3	0.50	43.0
Texas	0.47	70.9	*2.54*	29.9	0.63	-11.3	*1.47*	-4.5
Utah	*1.26*	102.8	0.15	-31.0	*2.31*	38.8	*1.75*	411.4
Washington	0.27	54.2	0.22	-8.7	1.03	25.8	0.91	93.8
San Diego	*1.57*	104.4	0.51	92.0	*2.72*	54.8	*3.66*	49.5
United States	1.00	44.8	1.00	12.9	1.00	16.6	1.00	44.0

Note: Italics indicate significant concentrations (location quotients equal to or greater than 1.2).
Source: Dun & Bradstreet *MarketPlace* 1995 (Q4) and 2001 (Q4); Battelle calculations. Bioscience is defined to include drugs (SIC 2833-2836), organic and agricultural chemicals (SIC 2869, 2873-2875, 2879), medical devices and instruments (SIC 3559-9922, 3821, 3826, 3841-3845), hospitals and laboratories (SIC 8062, 8063, 8069, 8071, 8072), and bioscience research and testing (SIC 8731-01, 8731-9902, 8733-01, 8734-9903, 8734-9908, 8734-9910).

Hospitals and laboratories dominate the Arizona bioscience sector to a greater extent than across the nation, exhibiting a local growth trend in the face of nationwide industry consolidation. Hospitals and laboratories account for 62 percent of the bioscience establishments in the state. The subsector employs more than 87 percent of Arizona bioscience workers, compared with 81 percent nationally (Figure 2). Nationwide, hospital and laboratory firms have turned to mergers, consolidation, and outsourcing to reduce costs, keeping employment levels nearly stationary. Yet in Arizona, the hospital and laboratory subsector has increased employment by 19 percent since 1995, nearly equaling the state rate of population expansion. This difference from national circumstances is rooted in rapid overall population growth (23 percent in Arizona between 1995 and 2001, compared with 8 percent across the United States) and a burgeoning elderly population. Since 1980, the proportion of residents aged 65 years or older has been increasing in Arizona at a 50 percent faster rate than nationwide. Arizona is forecast to be the home of 1.35 million elderly residents by 2025, presenting a severe challenge to the capacity of the state healthcare industry.

Figure 2. Bioscience Establishments and Employment by Subsector, Arizona and U.S. (2001)



Note: The larger figures represent the Arizona bioscience sector; the smaller figures show the U.S. distribution for comparison.

The medical device and instrument subsector has expanded its Arizona employment at more than three and a half times the national rate. The number of employees in the subsector increased by 62 percent between 1995 and 2001, in comparison to 17 percent national growth, and at the same time added more than a third to its Arizona establishment total. After hospitals and laboratories, medical device and instrument manufacturing is the largest Arizona bioscience subsector, with more than 4,100 employees spread across 186 establishments.

Medical device and instrument manufacturing is one of the more concentrated bioscience subsectors in Arizona, yet possesses a location quotient of only 0.60. In other words, Arizona is home to approximately 2,760 fewer medical device and instrument workers than would be the case if Arizona were to mirror the national distribution of private sector employment. Major Arizona firms in this subsector include W. L. Gore & Associates in Flagstaff, Medtronic in Phoenix, St. Jude Medical in Scottsdale, Impra (acquired by C. R. Bard in 1996) and OrthoLogic of Tempe, and MRI Medical of Tucson. Several Arizona establishments engaged in materials, optics, and information systems development currently enjoy, recognize, or carry the potential to develop strong linkages to the medical device subsector.[14]

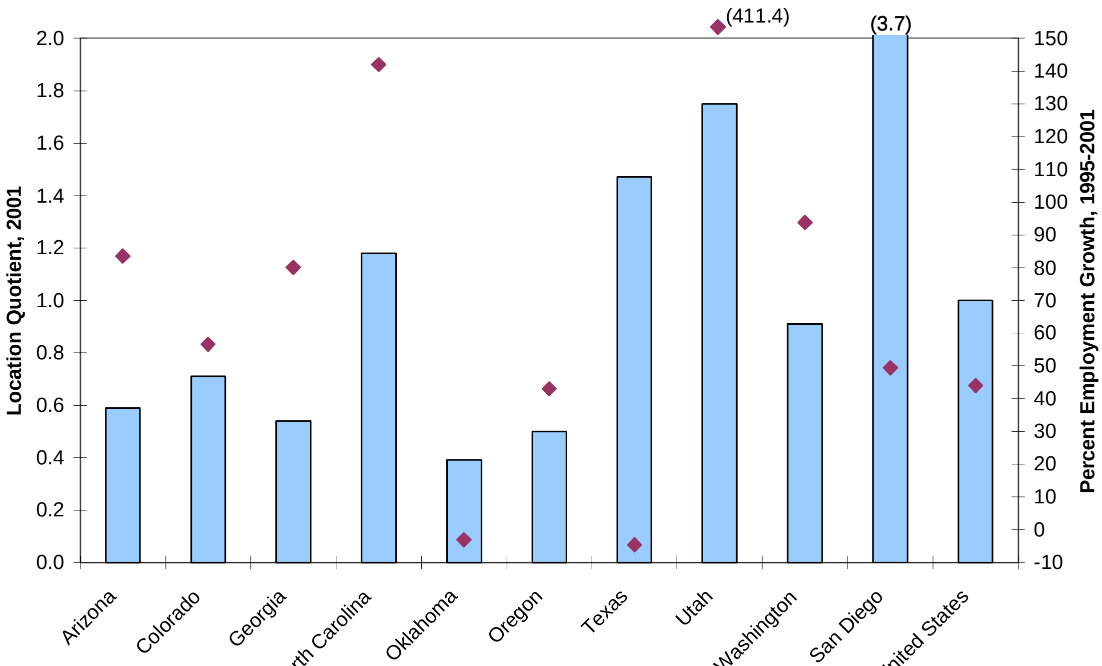
The remaining three bioscience subsectors are smaller in Arizona, employing about 1,500 to 2,000 workers each. Research and testing, the most dynamic of the bioscience subsectors at the national level, is somewhat more than half as concentrated in Arizona as across the nation, but has experienced rapid growth. The number of research and testing establishments has doubled in Arizona since 1995, slightly above the national increase of 80.8 percent. The

[14] This issue arising from technology convergence is discussed in more detail later in this section.

number of employees has risen by 83.6 percent in Arizona, nearly double the national rate, pushing the location quotient to 0.59 in 2001. Examples of Arizona research and testing firms include Selectide (an Aventis subsidiary) and Advanced Clinical Therapeutics in Tucson, Antech Diagnostics' Phoenix laboratory, Pivotal Research Centers with offices in Peoria and Mesa, and Instrumentation Metrics of Chandler.

Arizona's location quotient of 0.59 in research and testing ranks the state only seventh among the benchmarks. Figure 3 illustrates both the change in employment in research and testing between 1995 and 2001 and the benchmarks' location quotients. While employment in research and testing in Arizona increased, it is still lower than North Carolina, Utah, and Washington.

Figure 3. Research & Testing Employment Concentration and Growth



Source: Dun & Bradstreet *MarketPlace*, Battelle calculations.

Drugs, the fastest growing bioscience subsector at the national level in terms of employment, expanded at a similar rate in Arizona, increasing its workforce by 47.4 percent between 1995 and 2001. The number of establishments grew even faster, more than doubling from 46 to 110 in only six years. Lacking the large-scale manufacturing establishments present in the national subsector, the Arizona drug subsector instead is composed primarily of sales offices and small specialty pharmaceutical development outfits, such as Oxycal Laboratories of Prescott (part of the Nutraceuticals Group), Schein Pharmaceuticals (recently purchased by Watson Pharmaceuticals) and Zila in Phoenix, Medicis Pharmaceutical Corporation of

Scottsdale, and Tucson's ImaRx Therapeutics and Tucson Therapeutics. The location quotient for the subsector dropped slightly, from 0.26 to 0.23.[15]

Finally, the organic and agricultural chemicals subsector is about 70 percent as concentrated in Arizona as nationwide, up from only 30 percent six years earlier. Employment in organic and agricultural chemicals tripled from 1995 to 2001, adding 1,263 jobs across Arizona, whereas the subsector added only 12.9 percent in terms of employment nationwide. About half of this increase is due to the success and expansion of one company, Apache Nitrogen Products, Inc., of Benson, which survived a Superfund cleanup process and emerged as one of the premier nitrate producers in the nation. The rest of the employment increase is attributable to new or relocated industrial chemical and fertilizer firms, as well as the growth of existing chemical establishments. These include Tessenderlo Kerley, an arm of the Belgian company, Tessenderlo Chemie, producing chemicals for agriculture and mining; Fertizona, an Arizona-founded fertilizer manufacturer; and Gowan Milling, a chemical analysis and packaging company.

Examining metropolitan distribution at the subsector level reveals that Phoenix is particularly concentrated in drug manufacturing employment, whereas Tucson is strong in research and testing (Table 5). Bioscience activity on the national scale tends to cluster disproportionately in urban centers—to take advantage of locations proximate to academic and governmental bioscience-related research, to be close to transportation and communications infrastructure and other life science enterprises, and to be able to attract and retain highly educated and talented scientific and executive talent. Phoenix is the preferred location for regional sales offices for national pharmaceutical companies, as well as for small contract-dependent drug design and manufacturing operations that rely upon speedy yet affordable transportation links to the rest of the nation. Tucson, on the other hand, boasts a disproportionate segment of the state's private sector bioscience research and testing enterprise, profiting from being the site of the foremost medical school in the state.[16]

---

[15] Arizona's location quotient in drug manufacturing decreased slightly between 1995 and 2001, despite the fact that the subsector grew faster in Arizona than nationwide. This counter-intuitive outcome is a result of the rapid growth of the rest of the Arizona private sector economy during the time period of analysis. Because Arizona's entire economy expanded much faster than the economy of the United States as a whole, drug manufacturing employment rose as a share of national private sector employment faster than it did as a share of Arizona private sector employment, thus driving down the Arizona location quotient.

[16] The University of Arizona is in Tucson, and for most of the state's history was the sole medical school in Arizona. In 1992, Midwestern University established a college of health sciences at its second campus in Glendale, a Phoenix suburb (its original campus is in Downer's Grove, Illinois), adding a college of osteopathic medicine in 1995 and a college of pharmacy in 1997.

Table 5. Bioscience Distribution by Metropolitan Area, Arizona (2001)

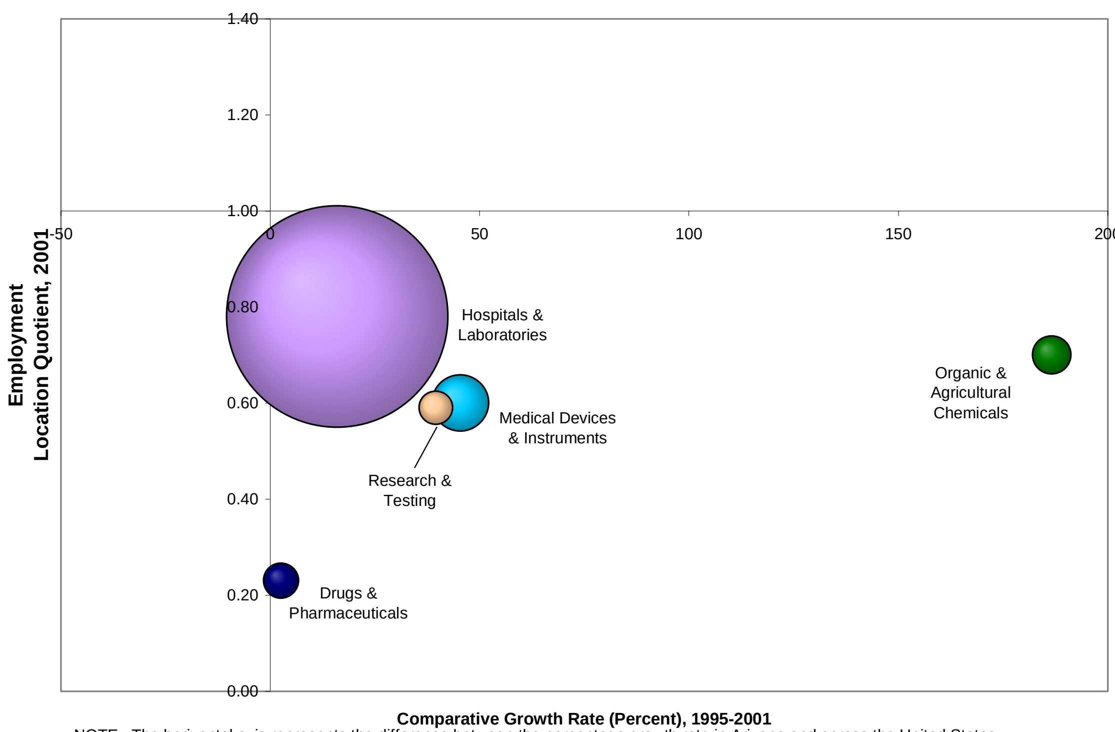
Metropolitan Area	*Bioscience Sector*		Drugs		Organic & Agric. Chemicals		Medical Devices & Instruments		Hospitals & Laboratories		Research & Testing		Population (2001, thousands)
	Establ.	*Empl.*	Establ.	Empl.	Establ.	Empl.	Establ.	Empl.	Establ.	Empl.	Establ.	Empl.	
Total	1,216	71,876	110	1,601	46	1,896	186	4,141	758	62,775	116	1,463	5,307
Phoenix	759	44,004	87	1,342	29	494	112	1,939	473	39,527	58	702	3,384
Tucson	225	14,138	11	64	3	192	46	964	125	12,215	40	703	863
Nonmetropolitan	232	13,734	12	195	14	1,210	28	1,238	160	11,033	18	58	781
Percent of Total													
Phoenix	62.4	61.2	79.1	83.8	63.0	26.1	60.2	46.8	62.4	63.0	50.0	48.0	63.8
Tucson	18.5	19.7	10.0	4.0	6.5	10.1	24.7	23.3	16.5	19.5	34.5	48.1	16.3
Nonmetropolitan	19.1	19.1	10.9	12.2	30.4	63.8	15.1	29.9	21.1	17.6	15.5	4.0	14.7
Percent Growth, 1995-2001													
Phoenix	15.2	(1.8)	123.1	30.9	11.5	20.8	20.4	80.5	1.5	(5.9)	65.7	119.4	27.1
Tucson	43.3	119.8	266.7	326.7	(40.0)	734.8	53.3	135.7	23.8	118.2	122.2	81.7	14.4
Nonmetropolitan	68.1	109.1	200.0	323.9	366.7	502.0	86.7	15.4	44.1	113.9	260.0	(35.6)	19.0

Data source: Battelle calculations from Dun & Bradstreet *MarketPlace* survey.

The nonmetropolitan portions of Arizona contain much of the state's employment in organic and agricultural chemicals and medical devices and instruments. Nearly two-thirds of organic and agricultural chemicals manufacturing is located in the nonmetropolitan counties. This situation is similar to other portions of the country, where the location of basic natural resources, convenient access to agricultural or pastoral end users, or unpleasant operating characteristics (externalities such as noise or odor) recommend dispersed rural sites. Apache Nitrogen Products, Inc., of Benson accounts for more than half of this employment. Also, 30 percent of medical device and instrument manufacturing is located in the nonmetropolitan counties of Arizona, most of which is attributable to the Flagstaff hub of W. L. Gore & Associates, Inc., for medical implant development and production.

Overall, Arizona's bioscience subsectors are in an emergent period, possessing certain specific strengths, sustaining remarkably rapid growth, but not as yet transformed into a fully mature economic sector. To provide a visual comparison of their various characterizations, Figure 4 classifies the five Arizona bioscience subsectors according to employment size, comparative growth rate, and relative concentration. The area of each disk corresponds to the amount of employment in that subsector. Each of the five bioscience subsectors falls into the bottom right-hand quadrant of the graph, with lower concentrations but faster employment growth rates than across the United States, thereby representing an emerging strength. Vibrant, mature sectors, those that have a greater concentration than the nation while still maintaining a faster growth rate, are found in the upper right-hand quadrant. From a policy standpoint, the goal is to move emerging industry sectors found in the lower right-hand quadrant into the upper right-hand quadrant.

Figure 4. Characteristics of Arizona Bioscience Subsectors



NOTE: The horizontal axis represents the difference between the percentage growth rate in Arizona and across the United States.

CONCLUSIONS

The bioscience sector is an important and growing part of the Arizona economy. Although it is still relatively small, several aspects of its growth mark it as emergent relative to the national sector. **However, recent gains in employment and establishments notwithstanding, Arizona requires a more focused development effort to achieve national levels of concentration in the biosciences.** In fact, at the current rates of expansion, Arizona would reach the national level of concentration in the biosciences in 43 years, or about half that time if the hospital and laboratory subsector was excluded. Obviously, this long-term prediction is not an exact science; no consideration is given to innumerable factors and variables whose shifts would impact future employment growth rates. Rather, Table 6 is intended to demonstrate how rapidly the State of Arizona is growing in several of the key bioscience subsectors and how far the state still must go to catch up to the nation as a whole.

Table 6. Arizona Bioscience Subsector Concentration Projections[17]

Sector	2001 Employment	1995-2001 Employment % Change	2001 Location Quotient	Time to Attain Location Quotient of 1.00 at Current Growth Rates
Organic & agricultural chemicals	1,896	199.5	0.27	3.3 years
Medical devices & instruments	4,141	62.0	0.60	16.0 years
Research & testing	1,463	83.6	0.59	25.3 years
Drugs	1,601	47.4	0.23	*not applicable* *
SUBTOTAL: Nonhospital biosciences	9,101	79.4	0.48	20.9 years
Hospitals & laboratories	62,775	19.0	0.78	39.1 years
TOTAL	71,876	24.3	0.72	43.0 years

* The location quotient for the drug subsector declined between 1995 and 2001, despite the fact that the subsector grew faster in Arizona than nationwide—an unusual outcome resulting from the rapid growth of the rest of the Arizona private sector economy. Because of this, it is not possible to use projections of current expansion rates to predict a future location quotient of 1.00.

Without directed actions to sustain and renew expansion in the biosciences, the current growth rates likely cannot be maintained by internal industry dynamics and momentum alone. Furthermore, even if present growth rates were to continue unabated, the time required for the state to reach national prominence in the biosciences is measured in decades. Therefore, the State of Arizona faces the challenge of finding ways to invest in and stimulate the biosciences to find and develop key niche areas in which Arizona can ascend to national prominence within a practicable time frame.

[17] This extrapolation is based on current growth rates. Because of the problems with using *MarketPlace* totals for private sector growth rates (see "Data and Methodology" and footnote 6), April 1998 and 2001 estimates of nonfarm employment from the Bureau of Labor Statistics were used to establish rates of employment growth for the Arizona and U.S. private sector economies (U.S. Department of Labor, Bureau of Labor Statistics, *Covered Employment and Wages*, available on-line at http://stats.bls.gov/cew/, April 23, 2002).

Assessment of Arizona's Position in Bioscience Research and Opportunities for Future Development

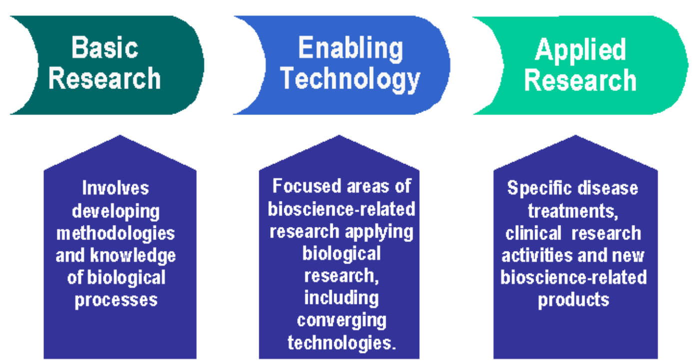
INTRODUCTION

A key element in developing a comprehensive bioscience strategy for Arizona is understanding the opportunities found across research activities in the biosciences, assessing their overall strength, and determining how best to support their future development. Research is critical to bioscience development. Without a strong bioscience research foundation, any region or state will find it difficult to initiate or sustain major industry development in the biosciences. This is no surprise, given the major emphasis on R&D by bioscience companies and the close connections between basic research discoveries and product development in the biosciences. On average, biotechnology companies spend over 50 percent of their revenues on R&D, while the overall health care industry spends approximately 11 percent of its sales revenues on R&D. Major research centers are not only the key to basic research discoveries that generate product leads for bioscience companies, but, more importantly, create an environment in which these bioscience companies can flourish. Moreover, research centers can be a key asset for the bioscience industry in bridging the gap between basic and applied research.

However, the purpose of this analysis is not for augmenting research alone, but for developing an integrated, comprehensive strategy for bioscience development. Of specific interest is how the bioscience research core competencies identified in Arizona can best be supported and leveraged to further translational activities leading to economic development of bioscience activity in the state.

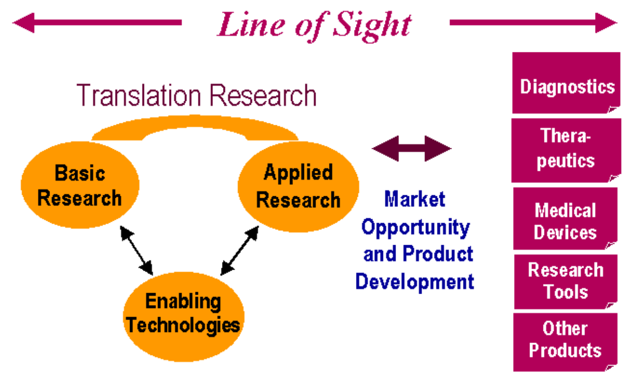
In assessing the technology platform potential of each of the bioscience core competency areas found in Arizona, the key concept is the robustness of the core competency area to address needs and market opportunities. What determines the success of a technology platform is the ability to pursue a "translational model" in which basic research and enabling technologies are brought together through applied research to address improved clinical treatment and market opportunities. As depicted in Figure 5, the component elements of a technology platform involve basic research, enabling technology, and applied research.

Figure 5. Components of Technology Platforms



Underpinning the development of a focused bioscience strategy building off of core competencies for Arizona is the recognition of the importance of "market-driven" processes (Figure 6). The traditional model of commercialization assumes a "research-driven" approach to commercialization. This research-driven commercialization process proceeds in a pipeline fashion from basic research leading to a major scientific breakthrough, to applied research leading to product development, and ending with industrial manufacturing and marketing. The shortcomings of the research-driven approach are that it is too divorced from commercialization and product development needs and has uncertain economic value. The market-driven approach recognizes that commercialization is a highly interactive process involving close ties between research activities and business development activities. Success depends, as the Council on Competitiveness points out, "on a team effort that includes carefully focused research, design for manufacturing, attention to quality and continuous market feedback."[18]

Figure 6. Market-Driven Approach to Technology Platforms



The components of a core competency area can bring together basic research, enabling technology, and applied research activities with a "line of sight" that moves seamlessly to address clinical needs and market opportunities and can form robust technology platforms. Core competency areas that lack this linkage and connection to needs and market opportunities offer more limited development opportunities.

However, before beginning to examine the market opportunities, a more thorough understanding of Arizona's strengths in basic research must be gained.

Overview of the Bioscience Research Base in Arizona

Taking stock of the overall trends and development of Arizona's research efforts is an important first step in assessing Arizona's bioscience research base.

From One Perspective, Arizona is Behind in the Biosciences Research Arena.

Despite a sizable base, Arizona's university research efforts have been lagging the nation. Based on research funding data compiled by the NSF, bioscience accounts for $229 million of university research in Arizona, or 44 percent of the university research base in the state. Still, Arizona falls far short of the national average of 57 percent that the biosciences account for in total university research.[19]

Benchmark Growth Rates

- Utah – 64.3%
- San Diego – 52.4%
- North Carolina – 42.0%
- Texas – 41.3%
- Colorado – 40.9%
- U.S. – 35.7%
- Washington – 33.8%
- Oregon – 32.1%
- Oklahoma – 30.5%
- Georgia – 29.2%
- Arizona – 27.5%

Arizona's national ranking in university-based bioscience research funding compiled by NSF is 27th in the nation, compared with its

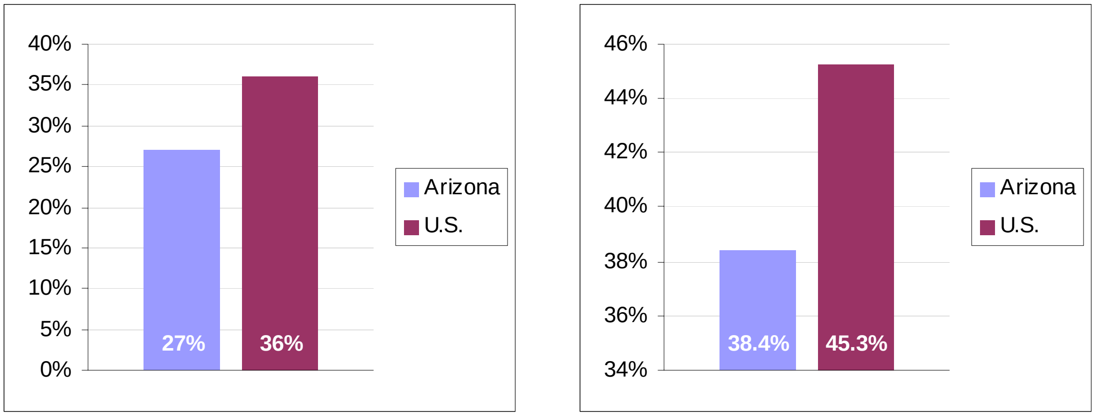
[18] Council on Competitiveness, *Picking Up the Pace: The Commercial Challenge to American Innovation* (Washington, DC: Council on Competitiveness), pp. 9-10.

[19] NSF, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Years 1996 and 2000, with Battelle calculations for percentage of overall research base.

total research ranking in all research fields of 21st.[20] Overall, Arizona's academic bioscience research expenditures are low in comparison to the benchmarks. Arizona ranked eighth in terms of total bioscience research, ahead of only Utah and Oklahoma.

Total bioscience research funding reported by NSF grew only 27 percent in Arizona from 1996 to 2000, compared with 36 percent for the nation (Figure 7).[21] More startling is the fact that Arizona's growth rate was less than every other benchmark state.

Figure 7. Arizona is Lagging Growth in Bioscience Research in Late 1990s

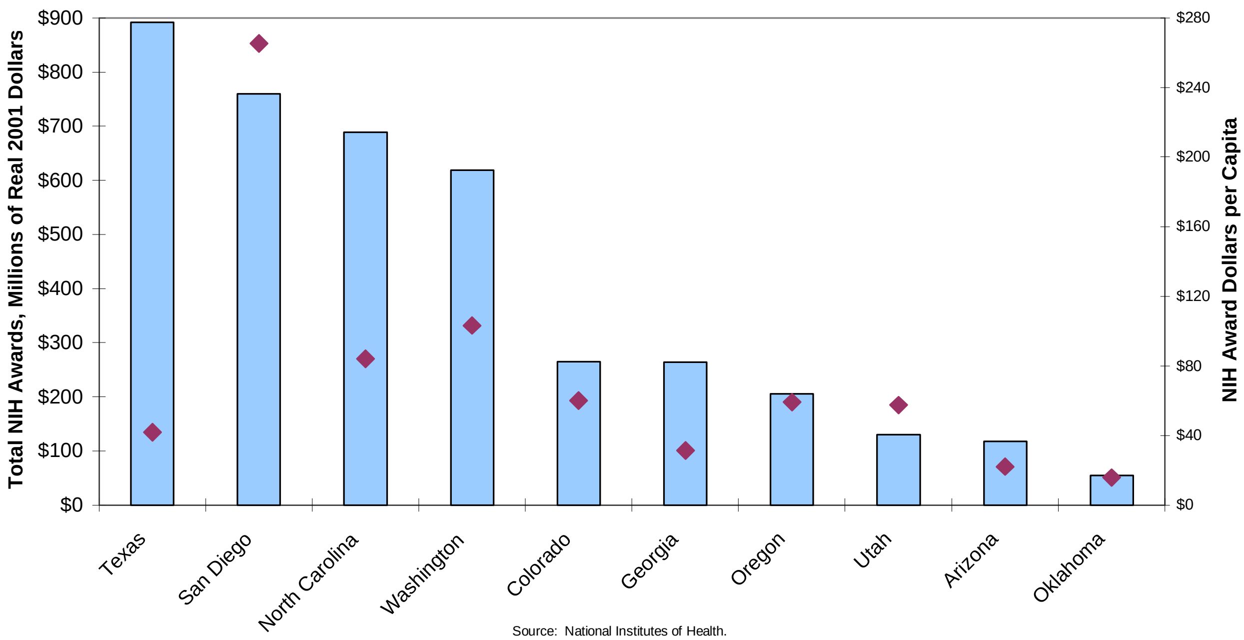


NIH funding, the gold standard of biomedical research funding, is also lagging in the State of Arizona. For FY 2001, Arizona received $117 million in research funding from NIH, placing the state 27th in the nation.[22] In addition, Arizona ranked ninth among the benchmarks both in terms of number of grants and total dollars awarded, leading only Oklahoma. As Figure 8 illustrates, this ranking is repeated on a per capita basis as well.

Growth in NIH funding from FY 1997 to 2001 stood at 38.4 percent in Arizona, which lagged all the benchmarks except Colorado (Figure 9). By comparison, the total national value of NIH awards increased by 45 percent, and award value in six benchmarks increased by more than this ratio. Therefore, Arizona is losing ground relative to these funding winners.

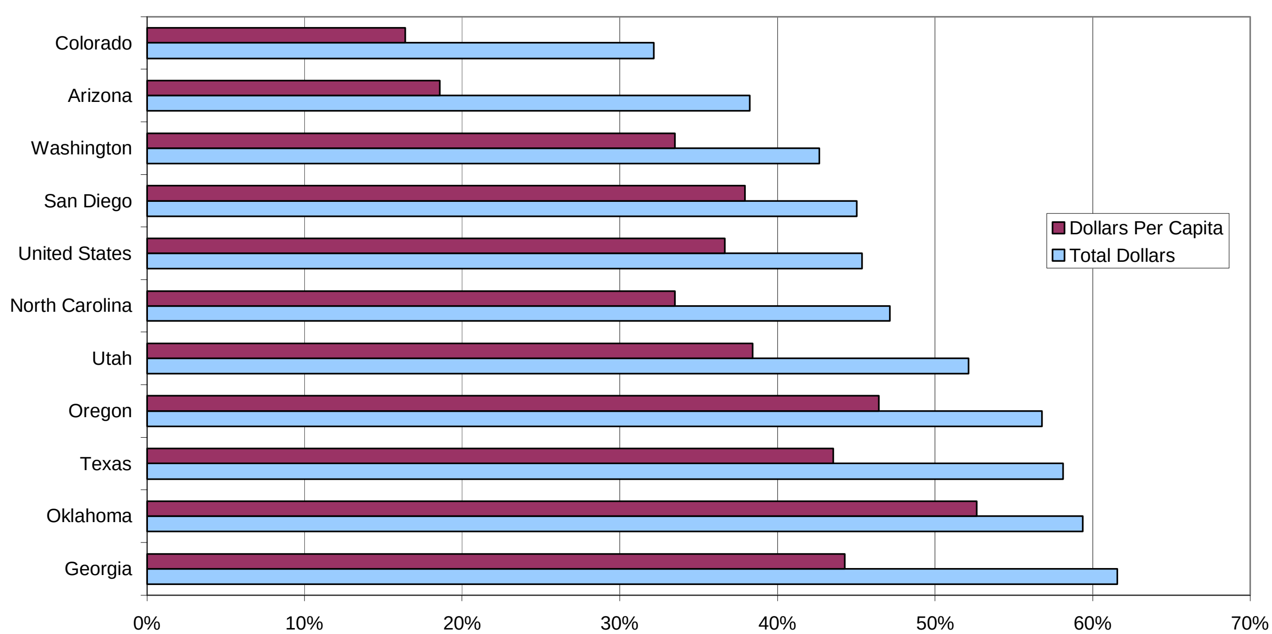
[20] NSF, Academic R&D Expenditures, with Battelle calculations for state rankings.
[21] NSF, Academic R&D Expenditures, with Battelle calculations for percentage changes in Arizona and the nation.
[22] NIH, Office of Extramural Research, FY 2001.

Figure 8. NIH Awards, Total and Per Capita (FY 2001)



Source: National Institutes of Health.

Figure 9. Percentage Change in NIH Awards, Total and Per Capita (FY 1997-2001)



Source: National Institutes of Health.

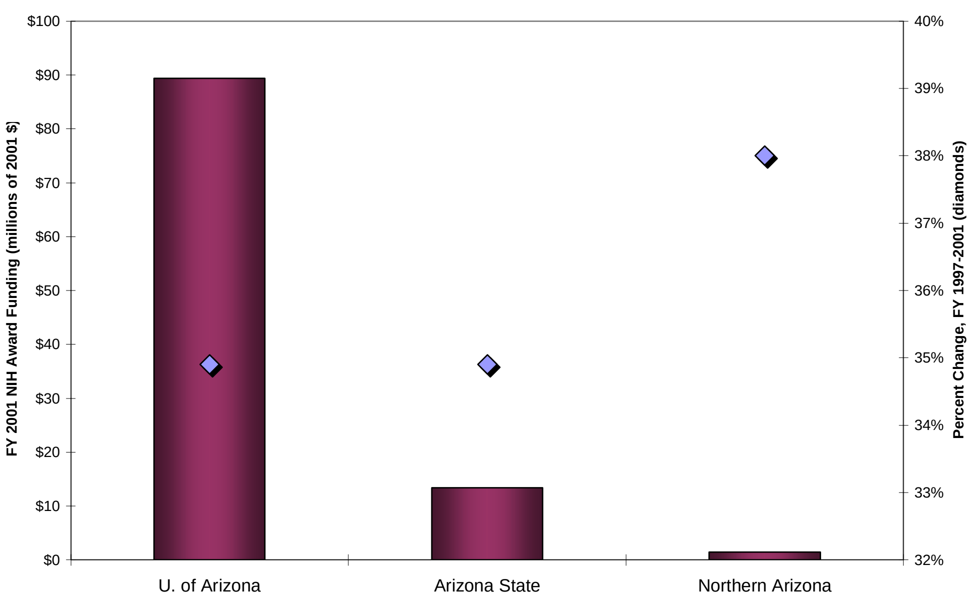
The University of Arizona dominates basic bioscience research in the state, yet is not among the top universities in the nation in bioscience research. As noted in Table 7, nearly $9 out of every $10 of all university bioscience research funding reported by NSF in Arizona is accounted for by the University of Arizona, and $8 out of every $10 of NIH-funded research as well (Figure 10). Yet, the University of Arizona, compared with all universities across the United States, ranks only 50th in NIH funding and 29th in total university bioscience research and development expenditures reported by NSF.

Table 7. Bioscience Research by Arizona Universities (FY 2000)

	U. of Arizona		Arizona State		Northern Arizona	
Field	Amount	% AZ	Amount	% AZ	Amount	% AZ
All Biosciences	$201.3	88.1	$19.2	8.4	$8.1	3.6
Biological Sciences	63.1	78.2	13.4	16.6	4.2	5.2
Medical Sciences	82.3	99.1	0	0.0	0.7	0.9
Agricultural Sciences	51.6	92.5	1.3	2.3	2.9	5.2
Bioengineering	2.1	53.8	1.6	39.3	0.3	6.9
Other Life Sciences	2.2	42.2	2.9	56.3	0.1	1.5

Source: National Science Foundation, Battelle calculations.
Notes: Dollar amounts in millions of real 2001 dollars.

Figure 10. FY 2001 NIH Awards to Arizona Universities



Within the broad fields of university-based biosciences—agricultural, biological, medical, and bioengineering—Arizona ranks poorly in biological and medical research and growth has been generally trailing the nation through the latter half of the 1990s, except in medical research. As noted in Table 8, in university-related research expenditures reported by NSF, Arizona ranks 18th in the nation for both agricultural and bioengineering research, but only 26th in biological research and 28th in medical science research. While medical research is outpacing national growth, agricultural research is slightly off the pace and biological sciences in Arizona are far off the national pace of growth.

Battelle

Table 8. Arizona Academic Bioscience Research

Field	FY 2000 Amount	State Ranking	% Change FY 1996-2000	FY 1996 Ranking	U.S. % Change FY 1996-2000
All Biosciences	$229	27	27.5	27	35.7
Biological Sciences	81	26	26.0	24	40.3
Medical Sciences	83	28	42.5	27	37.7
Agricultural Sciences	56	18	9.4	13	11.5
Bioengineering	4	18	n.a.	n.a.	n.a.
Other Life Sciences	5	30	-15.1	28	34.0

Source: National Science Foundation, Battelle calculations.
Notes: Dollar amounts in millions of real 2001 dollars; n.a. = not applicable (bioengineering not tabulated as a separate category for FY 1996).

On the Other Hand, What Arizona Has Been Able to Accomplish in Nonbioscience Research Over Past Decades, if Done in Bioscience Research, Represents a Key Target of Opportunity for Arizona.

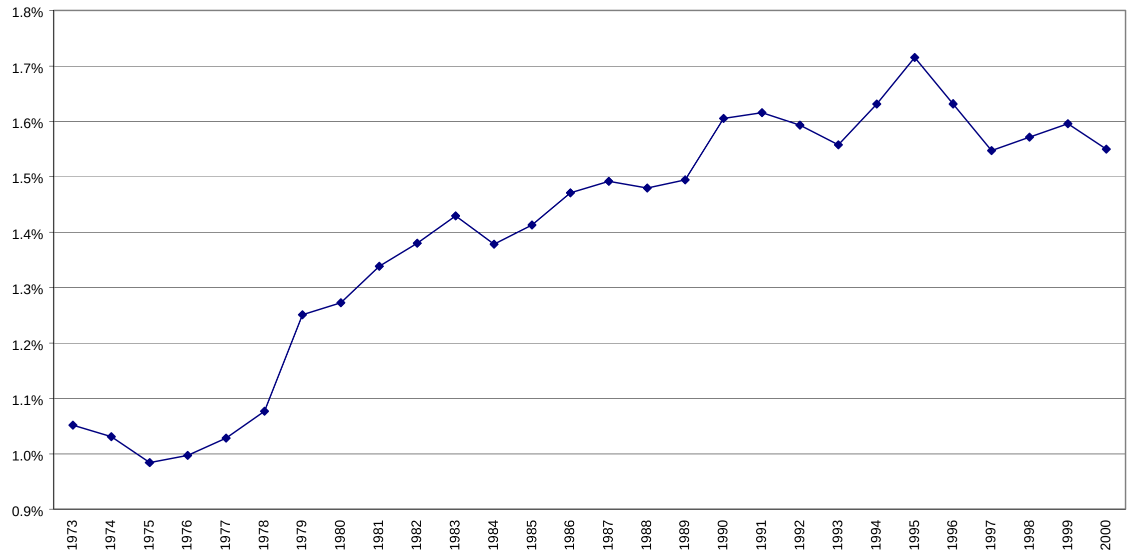
Arizona has risen sharply in research relative to the nation over the past 25 years. Most of this growth occurred in the late 1980s and early 1990s, however. More recently, Arizona's pace of growth has slowed—between FY 1995 and 2000, total academic research in Arizona reported by NSF grew only 16 percent, while total U.S. academic research climbed by 29 percent (Figure 11).[23]

Arizona has enjoyed its strong growth in basic research by becoming a national leader in key areas of natural science research, particularly astronomy, other physical sciences, and earth sciences/ecology. Based on NSF data for FY 2000 on university research expenditures, Arizona ranks as follows compared with the other 49 states[24]:

- Arizona is seventh in the nation out of the 50 states in university research expenditures in physical sciences, led by its ranking of second in the nation in university astronomy research.
- Arizona is seventh in the nation in university earth sciences/ecology research expenditures.
- Arizona is 17th in the nation in university engineering research expenditures overall, 11th in university mechanical engineering research, and 12th in university civil engineering research expenditures.

[23] NSF, Academic R&D Expenditures, with Battelle calculations of percentage change in total R&D growth.
[24] NSF, Academic R&D Expenditures, with Battelle calculation of state rankings for Arizona.

Figure 11. Arizona Academic R&D as Percentage of United States



Source: National Science Foundation

If Arizona's research universities can replicate in the biosciences the tremendous success they have had in the physical sciences, then Arizona can reverse the recent period of slower growth in overall research relative to the nation, which has occurred in the late 1990s. Given the major growth in bioscience research expected with the continued rise of the NIH's budget, Arizona can reap major benefits from bioscience research. Alternatively, if the state does not position itself more strongly in the biosciences, then its overall research base may continue to fall relative to the nation as it misses out on a federal government driver of research growth. Focusing on the biosciences can have a substantial impact on Arizona's research base. If Arizona in 2000 were at the national level of bio-science-to-total-university research funding as reported by NSF, it would mean an increase of nearly $150 million in bioscience university research activity in Arizona. This nearly 30 percent increase in bioscience university research funding would raise the state from 21st to 16th in the nation in overall research funding, have an immediate economic multiplier effect for the state's economy, and significantly enhance Arizona's ability to build on its bioscience strengths to develop commercial business within the state and take a more prominent position in tomorrow's economic environment.

If, in FY 2000, Arizona had equaled the national proportion of university bioscience-to-total-research funding, then its overall university research level would be $149 million higher, reaching $663 million and placing Arizona 16th in the nation, compared with its current 21st ranking in total research.

FOUR EXISTING AREAS OF BIOSCIENCE RESEARCH CORE COMPETENCY

While the overall research funding levels suggest that bioscience research activity is clearly lagging in Arizona, it is important to take a more detailed look at Arizona's current and emerging core competencies in the biosciences. Research core competency refers to those research areas where both concentration of activity and excellence are demonstrated by having

- A significant number of bioscience-related research grants awarded through rigorous peer-review processes such as those at NIH, NSF, and the U.S. Department of Agriculture (USDA).
- A broad base of principal investigators, along with prominent biomedical researchers who hold multiple peer-review grants.
- Substantial level and impact of publications.

This does not mean that other fields of bioscience research excellence are not present in Arizona. What it does mean is that these other bioscience strengths exist in relatively limited pockets and so offer more limited opportunities upon which to build.

Publications/Citations Analysis Approach

Level of effort threshold—At least 100 publications and at least equal to or greater than Arizona's overall percentage of publications.
Quality threshold—The ratio of citations to publications for Arizona should exceed the national average by 30 percent, or have a 30 percent higher "relative impact."

Key Areas of Research Core Competency

From analysis of peer-reviewed grant activity and publications activity, four areas of current research core competency have been identified in Arizona, namely

- Neurological research
- Cancer research
- Bioengineering research
- Agricultural, plant science, and environmental research.

Each of these areas is discussed in detail below.

Neurological Research—A strong core of neurological expertise in universities and medical centers is demonstrated by the award of nearly 100 peer-reviewed grants for neurological studies of various kinds. These research grants cover a wide range of basic to clinical research involving learning and memory, aging, Alzheimer's disease, movement disorders and motor control, neurobiology, and prosthetics. In addition, Arizona records strong publications/citations activity in related research fields of neurosciences, psychology, and neurology.

Grant Cluster Analysis:

Neurological Grant Cluster Areas			
Cluster Area	Number of Grants	Number of Principal Investigators	Leading Institutions Involved
Neural Mechanisms and Brain Function	98	76	University of Arizona Arizona State St. Joseph's Barrow Neurological Institute Sun Health Research Institute

Source: Grant data compiled by Battelle from NIH, NSF, and USDA new awards to Arizona for 1995 to 2002. Cluster analysis by Battelle applying proprietary Starlight software tool.

Publications Analysis:

Neurological Areas of Publications (At least 100 publications, publication concentration above Arizona average, and relative citation impact above 35% of U.S. average for field)			
Field	Publications	Publication Concentration Ratio	Percent Higher Relative Citation Impact Than Nation in Field
Neurology	105	1.12	67%
Neurosciences	608	1.07	24%
Psychology	938	3.07	50%

Source: Institute of Scientific Information, calculations by Battelle.
Notes:

- Publication Concentration Ratio measures percent of Arizona publications in field to percent of all publications in Arizona. Ratio above 1.0 indicates higher concentration of publications in field than all publications in Arizona.
- Relative Citation Impact measures percent of citations per publication in Arizona to percent of citations per publication for nation in that field. Battelle presents the extent to which Arizona exceeds national average.

Other evidence and examples of activities highlighting Arizona's core competency in this research area include the following:

- Highly regarded clinical care is present in neurology and neurosurgery, as identified by *U.S. News & World Report* rankings of the top 205 medical centers in the nation[25]:
  - University Medical Center in Tucson, ranked 18th
  - St. Joseph's Hospital and Medical Center in Phoenix, ranked 21st
  - Thunderbird Samaritan Medical Center in Glendale, ranked 46th.
- Arizona Center for Alzheimer's Disease Research, a collaboration of eight biomedical research institutions, is focused on the early detection and prevention of Alzheimer's disease.
- The new Institute for Mental Health Research, a partnership of the UA, ASU, Banner Health System, Barrow Neurological Institute, and Sun Health Research Institute, will foster interdisciplinary teams of scientists and clinicians, with the aim of making breakthroughs in child and adolescent psychiatry, neuropsychiatry, schizophrenia, and mood and emotions.
- Sun Health Research Institute maintains a brain donation program that is one of the largest in the nation, able to receive brain tissues close to postmortem and undertake a very detailed characterization of brain tissue to aid future research.
- ASU brings together its research efforts in motor control and neural engineering to bridge an understanding of how the central nervous system controls and regulates movement in healthy individuals and in those with neurological impairments.
- Neurobiological research at St. Joseph's Hospital, including the Barrow Neurological Institute, spans both clinical and basic research. Currently, 75 active neuroscience-related clinical studies are underway involving clinical drug studies, epidemiology studies, and national database formation. In addition, basic research is underway at St. Joseph's, from normal brain function and development to the understanding of neurological abnormalities through studies of brain tumors.
- UA has an interdisciplinary neurosciences program that involves a total of 52 faculty members across 18 departments and funding of approximately $10 million annually. An innovative linkage is the close relationship with the Center for Insect Science at UA to make extensive use of insects as models for studies of important neurobiological problem areas.

Cancer Research—Two major cancer-related cluster areas are identified through peer-reviewed grant activity, one involved in basic research involving apoptosis, tumors, and genetics and a more applied cluster involved in drug discovery, imaging, and clinical research. The cancer

[25] *U.S. News & World Report* methodology for identifying "America's Best Hospitals" was devised in 1993 by the National Opinion Research Center at the University of Chicago, which carries it out and refines it each year. The U.S. News Index accounts for reputation cited by a random sample of board-certified physicians in each specialty area over the past three years average; mortality statistics on deaths of Medicare patients with specified conditions in 1998, 1999, and 2000 with adjustments for severity; and other data from the 2000 annual survey of hospitals by the American Hospital Association, generally covering extensiveness of services. Selection of the top 205 is based on a hospital (1) meeting one of three standards: membership in Council of Teaching Hospitals, affiliation with a medical school, or availability of at least 9 out of 17 specified items of medical technology; and (2) being cited by a least one physician in the past three years of surveys on reputation or performing a given number of procedures.

research area also demonstrates significant publications activity. A distinguishing feature of Arizona's cancer research is its depth in advancing innovative new cancer therapies. This core competency will be significantly enhanced by the recent attraction of the International Genomics Consortium and The Translational Genomics Research Institute.

Grant Cluster Analysis:

Cancer Grant Cluster Areas			
Cluster Area	**Number of Grants**	**Number of Principal Investigators**	**Leading Institutions Involved**
Basic Cancer Research	35	23	University of Arizona Mayo Clinic of Arizona St. Joseph's Hospital and Medical Center Northern Arizona University
Applied Cancer Research	49	38	University of Arizona Arizona State University

Source: Grant data compiled by Battelle from NIH, NSF, and USDA new awards to Arizona for 1995 to 2001. Cluster analysis by Battelle applying proprietary Starlight software tool.

Publications Analysis:

Cancer Areas of Publications (At least 100 publications, publication concentration above Arizona average, and relative citation impact above 35% of U.S. average for field)			
Field	**Publications**	**Publication Concentration Ratio**	**Percent Higher Relative Citation Impact Than Nation in Field**
Oncogenesis & Cancer Research	276	1.20	35%

Source: Institute of Scientific Information, calculations by Battelle.
Notes:

- Publication Concentration Ratio measures percent of Arizona publications in field to percent of all publications in Arizona. Ratio above 1.0 indicates higher concentration of publications in field than all publications in Arizona.
- Relative Citation Impact measures percent of citations per publication in Arizona to percent of citations per publication for nation in that field. Battelle presents the extent to which Arizona exceeds national average.

Other evidence and examples of activities highlighting Arizona's core competency in this research area include the following:

- University Medical Center in Tucson is highly regarded for clinical care for cancer as measured by *U.S. News & World Report*, which ranks it 26th in the nation among the 205 top medical centers.
- The Cancer Research Institute (CRI) at ASU is dedicated to identifying and developing anti-cancer agents from natural products. CRI comprises an interdisciplinary team involving microbiologists, cancer cell biologists, and biochemists applying state-of-the-art techniques for isolation and separation analysis, in vitro cancer cell screening, X-ray crystallography and nuclear magnetic resonance (NMR) for structure analysis, and synthetic chemistry for modifying chemical agents.

- The recent attraction of the International Genomics Consortium to Arizona will locate activities involved with gene expression studies of cancer tissue drawn from 19 participating cancer institutes nationwide. The newly formed TGen is expected to establish a world-class initiative to provide a strong basic biological research emphasis for established strengths in cancer drug discovery in Arizona, including a major focus on cancer genetics as well as complementary areas of computational biology and proteomics.
- The UA Health Science Research Consortium is focusing on establishing a premier cancer clinical research network in Phoenix by funding collaborative research that brings clinicians and faculty researchers together to support Phase I clinical trials.
- The Sydney E. Salmon Pancreatic Cancer Program at the UA Arizona Cancer Center and University Medical Center is a major focused effort addressing prevention, improved diagnosis, and new therapies.
- The Cancer Center's Chemoprevention of Colon Cancer Program is the largest single-program project grant—funded by the National Cancer Institute (NCI) at more than $17 million. The funds will be used for three highly interactive scientific research projects and to complete two large clinical trials for the prevention of colon cancer in 2,800 participants.
- Northern Arizona University and the Arizona Cancer Center have been awarded a five-year, multimillion-dollar project to conduct cancer research, education, and outreach to address the disparity in cancer in American Indians of the Southwest.
- The Virginia G. Piper Cancer Center at Scottsdale Healthcare, which opened in 2001, serves as the home to the Arizona Cancer Center's expanded New Therapeutics Program for early-stage clinical trials and offers genetic risk assessment research and prevention research programs focusing on breast, colon, and prostate cancer.

Bioengineering Research—Arizona's strength in physical sciences involves a broad range of converging technologies that can be applied to bioscience solutions including new drug delivery and diagnostic and medical devices, as documented by NSF data on research expenditures and by publications activities. Peer-reviewed grant activity points to a critical mass of research in imaging for both medical and environmental purposes, involving a wide variety of technologies and techniques from magnetic resonance imagings (MRIs) to mammograms, biosensors, mass spectrometry, and optical microscopy.

Grant Cluster Analysis:

Bioengineering Grant Cluster Areas			
Cluster Area	**Number of Grants**	**Number of Principal Investigators**	**Leading Institutions Involved**
Imaging for Medical & Environmental Research	80	73	University of Arizona Arizona State Northern Arizona

Source: Grant data compiled by Battelle from NIH, NSF, and USDA new awards to Arizona for 1995 to 2002. Cluster analysis by Battelle applying proprietary Starlight software tool.

Publications Analysis:

Bioengineering Areas of Publications (At least 100 publications, and relative citation impact above 20% of U.S. average for field)			
Field	Publications	Publication Concentration Ratio	Percent Higher Relative Citation Impact Than Nation in Field
Medical Diagnostic Research	167	0.49	39%
Optics	395	2.51	53%
Spectroscopy/Instrumentation	260	0.78	33%
Materials	365	0.80	58%
Chemistry	205	0.61	125%
Electrical Engineering	378	1.61	50%
Engineering Management (systems engineering)	147	2.12	135%
Physics	833	1.29	40%

Source: Institute of Scientific Information, calculations by Battelle.
Notes:

- Publication Concentration Ratio measures percent of Arizona publications in field to percent of all publications in Arizona. Ratio above 1.0 indicates higher concentration of publications in field than all publications in Arizona.
- Relative Citation Impact measures percent of citations per publication in Arizona to percent of citations per publication for nation in that field. Battelle presents the extent to which Arizona exceeds national average.

Other evidence and examples of activities highlighting Arizona's core competency in this research area include the following:

- The Optical Sciences Center at UA provides an interdisciplinary, broad resource in optics, covering quantum optics, optoelectronics, optical communications, optical systems design and fabrication, and optical imaging systems and analysis.
- The Center for Gamma Ray Imaging at UA designs and constructs imaging instruments and studies the theoretical and computational aspects of optimizing their use.
- Multidimensional Image Processing Laboratory (MIPL) at UA develops new techniques for use in the processing and analysis of digital signals and images for a variety of applications.
- Barrow Neurological Institute (St. Joseph's Hospital and Medical Center) participates in ongoing clinical and basic neuroscience research to further the prevention and treatment of brain, nerve, and spinal cord diseases and injuries.
- Neural Engineering at ASU is highly crosscutting, including links with motor control research for direct brain control of a motor prosthesis, development of bioMEMs devices for neuroprosthetics systems, and development of bioactive coatings for implantable microelectrodes.
- The Center for High Resolution Electron Microscopy at ASU is the world's largest collection of electron and atomic force microscopes, offering micron to atomic scale resolution.
- The Center for Solid State Electronics at ASU has a specialty in optoelectronic materials and devices, including molecular beam epitaxy growth of III-V compound semiconductor materials, lasers, and detectors and their application to chemical and biosensing.

Agricultural, Plant Science, and Environmental Research—The agricultural, plant science, and environmental research area is very robust in Arizona. The peer-reviewed grant activity identifies several clusters involving genetics of plants, insects, animals, and humans examining structure/function, gene regulation, and other basic genetic processes; insect sciences involving entomologists, veterinary scientists, and plant scientists with significant applications to neurological research; and soil and water research focusing on ecosystem issues such as plant adaptation, arid lands, and watershed analyses. Publications/citations activity supports these findings, with Arizona demonstrating key strengths in plant science and ecology.

Grant Cluster Analysis:

Agricultural, Plant Science, and Environmental Grant Cluster Areas			
Cluster Area	Number of Grants	Number of Researchers	Institutions Involved
Genetics Involving Plants, Insects, Animals, and Humans	98	83	University of Arizona Arizona State Northern Arizona
Species Evolution & Ecology	79	71	University of Arizona Arizona State Northern Arizona Agricultural Research Service
Soil & Water Analysis	31	27	University of Arizona Arizona State Northern Arizona Agricultural Research Service
Insect Science	29	25	University of Arizona Arizona State

Source: Grant data compiled by Battelle from NIH, NSF, and USDA new awards to Arizona for 1995 to 2002. Cluster analysis by Battelle applying proprietary Starlight software tool.

Publications Analysis:

Established Strengths in Bioscience Fields (At least 100 publications, publication concentration above Arizona average, and relative citation impact above 35% of U.S. average for field)			
Field	Publications	Publication Concentration Ratio	Percent Higher Relative Citation Impact Than Nation in Field
Plant Sciences	397	1.43	114%
Ecology	808	2.31	28%

Source: Institute of Scientific Information, calculations by Battelle.

Notes:

- Publication Concentration Ratio measures percent of Arizona publications in field to percent of all publications in Arizona. Ratio above 1.0 indicates higher concentration of publications in field than all publications in Arizona.
- Relative Citation Impact measures percent of citations per publication in Arizona to percent of citations per publication for nation in that field. Battelle presents the extent to which Arizona exceeds national average.

Other evidence and examples of activities highlighting Arizona's core competency in this research area include the following:

- The Keim Genetics Laboratory at NAU is the nation's premiere institution for deoxyribonucleic acid (DNA) fingerprinting of bacterial pathogens and houses the world's largest collection of anthrax. The NAU focus represents a comprehensive genetics effort extending beyond microbial genetics to include conservation, ecological, and plant and animal genetics.
- ASU is developing specialized capabilities for using plant systems to produce vaccines—what are referred to as "edible vaccines"—and is positioned to be a national leader in this application.
- ASU's Department of Microbiology involves 15 faculty members performing research across a range of areas from biological control of disease-vectoring mosquitoes, to interactions of immune system, and central nervous system to antiviral cancer therapies that can inhibit growth of cancer cells.
- The ASU "living laboratory" of urban Phoenix, funded by a major NSF grant, is a unique capability for researching long-term effects of urbanization (e.g., reduction of green space, pollution, etc.) on health and disease patterns in plants, birds, amphibians, and mammals.
- The Department of Ecology and Evolutionary Biology at UA maintains five zoological collections that are Arizona's largest and among the nation's largest regionally oriented collections. They represent an irreplaceable resource of material and information on the unique biota of the southwestern United States and northwestern Mexico.
- UA's Integrative Graduate Education and Research Traineeship Program in Genomics focuses on evolutionary, computational, and functional genomics approaches to genome structure and function.
- The Plant Genomics Institute at the University of Arizona is headed by Rod Wing and Vicki Chandler's research on gene regulation with a focus on epigenetic regulation, i.e., heritable changes not mediated by DNA, but by chromatin.
- The Center for the Study of Early Events in Photosynthesis at ASU emphasizes the understanding of photosynthesis for food and energy.
- The Agricultural Research Service Western Cotton Research Laboratory identifies, describes, and quantifies genetic systems in cotton; identifies plant traits relevant to stresses prevalent in arid lands; and develops improved breeding.

IDENTIFYING PATHS TO DEVELOPMENT—ASSESSING ARIZONA'S BIOSCIENCE TECHNOLOGY PLATFORMS

Near-Term Technology Platforms

Identifying how Arizona's bioscience building blocks are linked together reveals that the technology platforms are limited, in large part, because of the current need for a stronger basic biological research capacity in Arizona.

The Battelle team judged that three of the four areas of core competencies in Arizona translate into full-fledged bioscience technology platforms for future development:

- Neurological-related technology platform (neurological sciences)
- Cancer drug discovery technology platform (cancer therapeutics)
- Bioengineering-related technology platform (bioengineering).

Neurological Diseases and Rehabilitation (Neurological Sciences)— Near-Term Technology Platform

Neurological disorders represent one of the largest and fastest-growing segments for therapeutics, involving a broad range of treatments that include anxiety, depression, epilepsy, Alzheimer's disease, Parkinson's disease, and multiple sclerosis, among others. Most of these therapeutic approaches are palliatives, there being no definitive cures yet for nearly all of these types of neurological and psychiatric disorders. In addition, major central nervous system injuries pose key challenges for rehabilitation.

Given the complexity of the brain, the most promising therapeutic strategies likely are to combine understanding of brain function from several systems, involving behavioral neurosciences, as well as traditional drug development strategies that use molecular biology, organic chemistry, and pharmacology.

Arizona has a strong core of neurological expertise within universities and medical centers as demonstrated by the award of nearly 100 peer-reviewed grants for neurological studies of various kinds. In addition, Arizona demonstrates strong publications/citations activity in related research fields of neurosciences, psychology, and neurology. This neurological-focused core competency appears to be a very robust technology platform. While the Battelle team interviews suggest that most research is in basic science, there is also substantial translation and clinical work in Alzheimer's disease and some in Parkinson's disease and epilepsy. In addition, there is a core of well-funded work in motor control. What makes Arizona distinct is that research drivers in the state not only address therapies to treat neurological-related disorders themselves, but they also have a strong focus on rehabilitation to deal with the conditions related to these disorders.

Specifically:

- Arizona State University is gaining a leadership position in neural engineering, the interface between the nervous system and artificial devices that replace lost senses or missing limbs.
- The new Institute for Mental Health Research, a partnership of the University of Arizona and Arizona State University, Banner Health System, Barrow Neurological Institute, and Sun Health Research Institute, will foster interdisciplinary teams of

Key Research Strengths in Arizona in Neurological-Related Research Platform

- Neurobiology
- Neural Engineering
- Motor Control
- Imaging

Key Research Drivers Associated with Neurological-Related Research Platform

- University of Arizona
- Arizona State University
- Barrow Neurological Institute
- Sun Health Research Institute

Key Application Areas

- Alzheimer's Disease
- Rehabilitation
- Parkinson's Disease
- Epilepsy

scientists and clinicians from psychiatry, psychology, genetic engineering, psychopharmacology, neuroscience, bioengineering, and a number of related fields with the aim of making breakthroughs in child and adolescent psychiatry, neuropsychiatry, schizophrenia, and mood and emotions.

In regard to the market, Standard & Poor's reports that neurological and psychiatric drugs are the largest drug segment, accounting for 21 percent of all drug sales, and one of the fastest growing at 19 percent in the 12 months ending August 2000, based on IMS Health Inc. data. The largest market segments are antidepressant drugs (estimated at $21 billion in 2000) and antipsychotic drugs (estimated at $10 billion in 2000).

Neurological medical devices has a worldwide market of over $2.4 billion and is one of the fastest-growing biomedical market segments, with an annual growth rate of 20 percent. A wide range of products fall into neurological medical devices, such as neuromodulation devices for electrical stimulation and drug delivery, spinal fixation, diagnostics, and surgical instruments and systems.

Cancer Drug Discovery and Development (Cancer Therapeutics)—Near-Term Technology Platform

Cancer diseases are the second leading cause of death in the United States and presently have no known cure. There is no one underlying cause of cancer, but many; and so no single treatment can be expected. Nevertheless, what is common across cancer diseases is the runaway growth of mutated cells as a result of either inherited genetic mutations or genetic interaction with environmental factors. The key fundamental mechanisms of cancer diseases are either rapid development of mutated cells or a defect in a tumor-suppressor gene that no longer halts excessive cell division. Advances in new therapies can be of great significance, given that the traditional treatment of cancer using chemotherapy and radiation has not changed radically over the past two decades.

A distinguishing feature of Arizona's cancer research is its depth in advancing innovative new cancer therapies. For instance:

- The Cancer Research Institute at Arizona State University is one of the leading natural products groups in the nation.
- The University of Arizona Cancer Institute has developed a specialized focus on drug discovery that distinguishes it from its other cancer center peers.
- The formation of IGC and TGen targets a need for providing more focused effort in cancer genetics and cancer biology research. The IGC will carry out gene expression studies of cancer tissues; TGen will, over the next five years, house up to 250 scientists working on

Key Research Strengths in Arizona in Cancer Drug Discovery Research Platform

Existing
- Drug Discovery

Emerging
- Cancer Genetics
- Clinical Research

Key Research Drivers Associated with Cancer Drug Discovery Research Platform

- University of Arizona
- Arizona State University
- IGC and TGen (future)

Key Application Areas

- Pancreatic Cancer
- Colon Cancer
- Natural Products for Innovative Drug Agents
- Impact of Environment on Cancer

genomics as well as computational biology and proteomics, with a strong orientation on translational research in cancer, but growing into other disease areas.

- The University of Arizona Health Science Research Consortium is addressing the need for a robust cancer research platform that includes an extensive, multi-institutional clinical research effort, which can collect tissue-based patient databases and conduct clinical trials.
- The newly launched Piper Cancer Center, a collaboration of Scottsdale Healthcare and Arizona Cancer Center, offers an expanded therapeutics program for early-stage clinical trials, and genetic risk assessment research and prevention research programs focusing on breast, colon, and prostate cancer.

The report by Find/SVP on "The Market for Cancer Therapeutics" estimated the world market for cancer therapies was $15.4 billion in 1998 and is expected to grow by 14 percent annually, reaching $29 billion in 2003. The market includes chemotherapeutics, blood cell factors, chemopreventatives, immunological therapies, and novel therapeutics. The U.S. market for cancer therapies was $5 billion in 1998 and is growing at a rate of 10.7 percent annually.

Key Research Strengths in Arizona in Bioengineering-Related Research Platform

Existing

- Physical Sciences
- Optics & Medical Imaging
- Materials
- Analytical Chemistry
- Electronics
- Computer Sciences

Emerging

- Tissue Engineering

Key Research Drivers Associated with Bioengineering-Related Research Platform

- University of Arizona
- Arizona State University
- BNI, Good Samaritan

Key Application Areas

- Imaging & Diagnostics
- Implants
- Prosthetics
- Robotic Systems

Bioscience Instruments and Devices (Bioengineering)—Near-Term Technology Platform

A revolution is taking place in advanced medical treatments involving the convergence of nonbioscience technologies to advance biomedical applications. At its core, bioengineering bridges the engineering, physical, life, and medical sciences. It is concerned with applying principles and methods from engineering to understand, define, and solve problems in medicine, physiology, and biology.

Arizona's strength in physical sciences, documented by NSF data on research expenditures and by publications activities, provides a significant base upon which to pursue bioengineering applications. Peer-reviewed grant activity and interviews with researchers point to a critical mass of research in medical imaging and growing interest in this area, both for its contribution to clinical studies and general medical diagnostics.

Specifically:

- The University of Arizona's Optical Sciences Center has unique capabilities in advanced imaging systems that, for example, combine optical microscopy with MRI. In addition, broader applications, such as the use of the diode laser for tissue ablation, could make a great impact on cancer treatment and tissue remodeling.
- Strengths are emerging at both universities in biomaterials/biomimetics. These contributing capabilities are very important for building a preeminent bioengineering core. Materials,

combined with electronic design and software, are the keystones for biodevices of all kinds; and it appears that Arizona is well positioned to capitalize on this trend based on the combined materials and electronics strengths.

- Arizona has a strong foundation in applied mathematics and computer science and engineering in ASU and UA, and a few small groups are known nationally. What is particularly interesting is the applications orientation of the research in this area—electronics, optical computing, optoelectronics, materials, biology, medicine, and the environment. In particular, the synergism with electronics and electrical engineering is noteworthy. This implies good interdepartmental collaborations and teamwork, which can be applied to new bioscience problems as they emerge.

In addition, opportunities for local company interactions seem strong. Overall, biomedical devices is one of the more sizable and fast-growing bioscience sectors in Arizona. Also, interviews with researchers identified a growing number of company interactions and common development interests.

Standard & Poor's reports that the global medical device and products industry generated sales of about $165 billion in 2000, up about 10 percent from 1999. *U.S. Industry & Trade Outlook for 2000,* prepared by the U.S. Commerce Department and DRI, projects a very positive market for the medical device and products industry for five years, with 5 to 8 percent annual growth projected through 2004. Specifically, major growth is found in new medical technology products, such as lasers (15 percent), cardiovascular devices (12.4 percent), minimally invasive surgery (8.9 percent), and wound care products (12 percent). Innovative technologies and applications expected to show strong growth include the MEMS market, estimated at $10 billion and expected to reach $34 billion by 2002, with the fastest-growing sectors being bioMEMS and biomedical nanotechnology. The biosensors worldwide market, estimated by Dorland's Biomedical at $450 million in 1998, is growing at an annual rate of 5 percent per year.

Long-Term or Niche Technology Platforms

The Battelle team judged that the agricultural/plant science/environmental-related core competency is not a well-situated path for future development and should be viewed as an opportunity for future development rather than a near-term growth potential. Based on the intelligence gathered, it is more appropriate to break this agricultural/plant science/ environmental-related core competency into two potential technology platforms—one for infectious diseases and the other for ag-biotech. Each of these platforms, however, suffers some key weaknesses:

- Infectious diseases builds on the strength in ecology and plant science and the emerging strength in microbiology. But, this area has key gaps in the range of applications and in basic bioscience research foundations, particularly in immunology.
- Ag-biotechnology in Arizona possesses major strengths in basic biological research, especially genetic analysis, but has key gaps in enabling technology fields and a weak position in applications.

Interviews identified two other opportunities for future development in the emerging areas of

- Asthma
- Diabetes.

Infectious Diseases—Long-Term or Niche Technology Platform

Infectious diseases are in the headlines today because of new threats of bioterrorism. Infectious diseases comprise a large family of diseases characterized by an attack on the body by an external organism. Four major categories of infectious diseases exist: bacterial infections; viral infections running the gamut from the common cold to HIV/AIDS; fungal infections responsible for a variety of conditions that usually occur in moist tissue, including thrush in the throat or mouth and athlete's foot, as well as eye and ear infections; and parasitic infections such as malaria and tapeworms.

Key Research Strengths in Arizona in Infectious Diseases Research Platform

Existing

- Ecology & Evolutionary Biology
- Plant Vaccine Development

Emerging

- Microbiology

Key Research Drivers Associated with Infectious Diseases Research Platform

- Northern Arizona University
- University of Arizona
- Arizona State University

Key Application Areas

- Anthrax, Plague, and Other Biological Pathogens
- Plant Vaccine Development
- Valley Fever

Specific Arizona strengths include the following:

- Arizona is one of the nation's leaders in ecology, specifically regarding arid land ecology, which addresses water resources and adaptation, and urban ecology. However, Arizona needs to make further strides in identifying the opportunities for leveraging its knowledge of ecology in addressing infectious diseases. For instance, the environmental factors now being manifested in plants, insects, etc., could be models for human reactions. Plants and insects are already being used for human health models at UA, and ASU is considering expanding its urban ecology program into infectious diseases (or environmental health). Another important application in the future will arise from studies that seek to understand changes in ecosystems that are associated with global warming.
- Northern Arizona University's Keim Laboratory offers a unique and valuable platform for Arizona to actively contribute to research relating to bioterrorism and bacterial diseases more broadly. The Keim Laboratory is nationally noted for its leading research efforts in anthrax, and it is broadening its focus on a larger array of biological pathogens. Another program at NAU involves the isolation and characterization of antibiotics called "halocins" with a potentially novel mechanism of action, providing a way to attack bacteria that have become drug resistant.
- Arizona also leads the effort in using plants to produce "edible" vaccines. Current vaccines available must be injected, with the exception of the oral polio vaccine. A program is underway at ASU to develop edible vaccines produced in plants. Recent advances in this program have resulted in one human trial using potatoes that were engineered to stimulate immune responses against the Norwalk virus that causes intestinal disease. This was the first known trial of edible vaccines in humans. Other vaccines under study include Hepatitis B and cholera. In addition, plants could be genetically engineered to produce therapeutic

proteins such as antibodies. Antibody therapy might form a first-line approach to infectious disease outbreaks, in conjunction with antibiotic treatments. An important aspect of plant-derived vaccines is a much lower cost than conventional vaccines, estimated at a fraction of a cent per dose.

Infectious diseases remain the world's leading cause of premature death. The worldwide market for therapies against infectious diseases, upon initial consideration, seems quite large, estimated at over $37 billion in 2000 and growing at 8 percent each year, according to Dorland's Biomedical. Two-thirds of the market, however, is found in antibiotics used to treat bacterial infections, which are common in the developed world. Of the $5 billion in antiviral therapies, more than half of the market is accounted for by one infectious disease—HIV/AIDS.

A recent factor helping to drive the focus on infectious diseases is the threat of bioterrorism. From anthrax to small pox to polio, there are significant concerns that terrorists can use potent, highly contagious infectious diseases to attack Western nations. The full scale of the related R&D opportunities is still emerging, but is expected to be in the billions of dollars from federal, state, and local governments as well as private organizations. A recent announcement from the National Institute of Allergy and Infectious Diseases (NIAID) detailed a plan for spending more than $1 billion for new bioterrorism research. However, two key factors have held back the market for vaccine development:

- The lack of purchasing power in the developing and Third World nations, which have the highest incidence for many infectious diseases.
- High product liability due to safety concerns for traditional vaccines that use either live viruses or inactivated viruses to solicit a lasting immune response.

Ag-Biotechnology

Applying the tools of biotechnology to plants and animals offers substantial opportunities. In plant science, increased resistance to insects as well as improved traits are advanced using genetic engineering. Moreover, genetic engineering and other biotechnology applications are improving the diagnosis and treatment of animal diseases. Innovative cross-over applications are also possible with advances in biotechnology, such as nutraceuticals in which biologically modified food sources are used to deliver specific therapeutic effects.

In Arizona, plant genetics is an area of concentration in grant activity as well as a leading area of publications activity. This research provides fundamental understanding of genetic mechanisms in plant structure, functions, and diseases. It offers a basic research foundation for addressing agriculture-related efforts. One key asset is the Arizona Biomedical Institute at ASU, headed by Charles Arntzen, who is among the national leaders in engineering human proteins in plants.

In addition, a base of potential industry partners appears to be growing in the state. The organic and agricultural chemical industry in Arizona is showing signs of underlying strength. Employment tripled from 1995 to 2001, adding 1,263 jobs across Arizona; whereas, the subsector added only 12.9 percent in terms of employment nationwide. About half of this increase is due to the success and expansion of one company, Apache Nitrogen Products, Inc., of Benson. The rest of the employment increase is attributable to new or relocated industrial chemical and fertilizer firms, as well as the growth of existing chemical establishments. These include Tessenderlo Kerley, an arm of the Belgian company, Tessenderlo, producing chemicals for agriculture and mining; Fertizona, an Arizona-founded fertilizer manufacturer; and Gowan Milling, a chemical analysis and packaging company. Battelle is aware of a growing cluster of firms interested in nutraceuticals, including Zila, United American Industries, Matrix, and Marlin Nutraceuticals.

Food and agricultural biotechnology is a key focus for the agribusiness sector. The U.S. market for genetically engineered crops was more than $15 billion in 1999. From 1996 to 1998, acreage for genetically engineered crops grew from 8 million to 50 million. The retail market for functional foods is estimated to be growing at 16 percent per year, reaching $17 billion in 2000. Finally, food safety diagnostics is another growing area. The detection and diagnostic market is expected to grow from $250 million to $1 billion over the next five years with advanced immunoassay and other probe technologies.

Asthma

Asthma is a chronic, inflammatory lung disease characterized by recurrent breathing problems. People with asthma have airways that narrow more easily than non-asthmatics and are usually allergic to inhaled allergens. The causes of the airway abnormality and its relationship to being allergic are not known. Multiple factors seem associated with asthma, and each person with asthma reacts to a different set of factors. Identification of these factors in an individual is a major step toward learning how to control an asthma attack. Much study is underway on the role of genetic factors in asthma.

Although no core competency level of activity is demonstrated in asthma-related research in either grant or publications activity in Arizona, the Arizona Respiratory Center offers a growing platform, with existing capabilities for supporting population genetics analysis and other research endeavors. A key resource strength in Arizona is its access to population groups affected by asthma and other related respiratory diseases, including Hispanics, the elderly, and American Indians.

The asthma market is estimated at more than $8 billion. However, it is a very competitive market, with more than 20 companies actively participating in the U.S. market, including AstraZeneca, Aventis, Boehringer Ingelheim, Glaxo Welcome, and Schering-Plough.

Diabetes

Endocrine diseases focus on hormones such as insulin that are vital to the management of bodily systems. Diabetes is a disease resulting from deregulated metabolism of carbohydrates.

Although no core competency level of activity is demonstrated in diabetes-related research in either grant or publications activity in Arizona, the National Institute of Diabetes, Digestive and Kidney Diseases (NIDDK) of the NIH has a branch laboratory in Phoenix capable of carrying out the epidemiological studies. Collaborations are necessary for genomic evaluations of diabetic patient samples. In addition, members of the Pima Indian Tribe have an 80 percent chance of developing type II diabetes. The population at Gila River has presented researchers with a long-term study group that has enabled key risk factors to be identified and some interventions to be successful.

Dorland's Biomedical reports an $8 billion a year market for diabetes therapies growing at an annual rate of nearly 17 percent, with many key therapies growing well in excess of 20 percent.

Currently, leading drug companies mainly dominate the diabetes market, led by Novo Nordisk, Merck, Bristol-Myers Squibb, and Eli Lilly.

Summary of Arizona's Bioscience Technology Platform Opportunities

Table 9 provides a summary of the three near-term technology platforms and the four long-term technology platforms to build Arizona's bioscience base.

Table 9. Technology Platform Linkages Across Core Competencies: Current and Emerging

Technology Platform	Basic Research	Enabling Technology	Applications
Areas Judged by Battelle to Have Near-Term Growth Potential Over Next Five Years			
Neurological Sciences	Neurobiology	Neural Engineering Motor Control Imaging Clinical Research Insect Science	Alzheimer's Disease Parkinson's Disease Epilepsy Rehabilitation
Cancer Therapeutics	Genomics (with new IGC/TGen)	Drug Discovery Clinical Research	Anticancer Drugs Pancreatic Cancer Colon Cancer Environmental Links to Cancer
Bioengineering	Physical Sciences	Bioengineering Optics Materials Analytical Chemistry Electronics Imaging Computer Science	Imaging & Diagnostics Implants Prosthetics Robotic Systems
Areas Judged by Battelle to be Opportunities for Future Development			
Infectious Diseases	Microbiology	Plant Vaccine Development Ecology & Evolutionary Biology	Anthrax, Plague, and Other Pathogens Plant Vaccine Development Valley Fever
Ag-Biotech	Plant Genomics		Crop Development Nutraceuticals
Asthma	Genetics	Clinical Research	Asthma
Diabetes		Clinical Research Stress Research	Diabetes

LONG-TERM ENHANCEMENTS AND INVESTMENT NEEDS FOR STRENGTHENING ARIZONA'S BIOSCIENCE BASE

As Arizona acts to seize the potential of its near-term opportunities to build upon key areas of strength, a broader, sustained effort of investment in the overall bioscience research capacity is essential. As suggested by the overall assessment of research strengths, the three principal areas for investment are

- Strengthening basic biological sciences
- Broadening clinical research infrastructure
- Pursuing interdisciplinary, interinstitutional research.

Recommendations of investments in these three areas are presented as follows.

Strengthening Long-Term Basic Biological Science Investments

Arizona has many gaps in its basic biological sciences. While specific areas of basic biological science enhancement will further particular platform areas, such as endocrinology for diabetes and immunology for infectious diseases, Arizona must have a high-quality, robust depth in cross-cutting basic biological sciences that will ensure a strong foundation for developing Arizona's research competencies. Just as molecular biology revolutionized modern biological sciences over the past 20 years, key fields will lead to new fundamental biological understanding in the years ahead. Arizona must invest in the following key fields, which are not currently deep in Arizona:

- Cell and development biology
- Functional human genetics
- Proteomics
- Computational biology.

Beyond the particular fields of basic biological sciences, Arizona needs to ensure a sustained effort to be competitive in the biosciences. Arizona, in the past, developed research strengths in key niches of the physical and ecological sciences that do not face the stiff national competition found across the biosciences. Frankly stated, nearly every state and region of the nation is hoping to strengthen its bioscience competencies given the need, indeed the prerequisite, of research excellence if it is to be successful in becoming a major economic center.

Arizona has taken significant and meaningful steps to augment its state support for bioscience research with its 301 funding, support for TGen, and the voter approval to dedicate new tobacco tax revenues in part to additional research. These efforts must be sustained over a long period of time.

Of particular importance is Arizona's need to provide more flexibility for its research universities to compete for and retain emerging and existing "star" faculty, with state-of-the-art facilities, recruitment packages, and competitive salary packages. Without this flexibility, it will be difficult for Arizona to compete for the best talent.

Broadening Bioscience Clinical Research Infrastructure

As identified through the assessment of technology platforms, Arizona has only limited areas of application strengths today in specific diseases—namely, cancer and neurological disorders—with a foothold to become a more prominent player in infectious diseases, asthma, and diabetes. A more fundamental way to state the need in Arizona is that clinical research across a variety of diseases needs to be strongly promoted and supported.

Arizona can be a significant player in clinical research because it provides relatively easy access to a number of populations that are important for clinical studies and trials of new therapeutic approaches. These populations include aging subjects, Hispanics, and American Indians.

To take advantage of the access to patients, a system is needed to conduct replicable clinical studies and trials that involves all of the medical centers in the state. Some excellent foundations are being laid in Arizona, such as the Arizona Center for Alzheimer's Disease Research, which is a collaboration of eight biomedical research institutions from across the state, involving universities and medical centers. The University of Arizona Health Science Research Consortium is another excellent approach that offers a clinical research organization infrastructure involving clinical research nurses and information management systems, as well as funds collaborative research that brings clinicians and faculty researchers together to support Phase I clinical trials. More of these types of efforts are needed. TGen is oriented in this same collaborative fashion and can be an important asset in the years to come.

Another key investment that can be leveraged across disease research areas is the development of a statewide capacity to create genetic patient databases. Central to conducting leading-edge, genetic-based disease research is the ability to develop patient databases offering access to DNA samples and medical records. Given the importance of privacy and informed consent, the process of recruiting patients to be part of the databases is complex and requires a systematic effort involving a team of nurses and medical records technicians working in tandem with physicians and pathology labs.

Only by finding mechanisms that promote inclusion, collaboration, and incentives for clinical research across all research drivers, medical institutions, and physician practices can Arizona take advantage of its population assets for medical research and become a top-notch player in the United States. There is no one-size-fits-all approach; a climate needs to be created and supported by key infrastructure investments.

Pursuing Interdisciplinary Research

Perhaps the most significant niche for Arizona overall is promoting collaboration to infuse the deep enabling technology fields in areas such as imaging, optics, materials, motor control, and electronics found in Arizona widely across higher education and aligning these research activities to the biosciences.

The most challenging and significant research issues need to be addressed in ways that integrate and pursue interdisciplinary approaches. As a recent article in the *Chronicle of Higher Education* notes: "[interdisciplinary] partnerships are proliferating in academe—and slowly changing the face of science—because they offer the best hope for answering some of the thorniest research subjects including climate change, biodiversity and cancer."[26] More specifically, in the biosciences, interdisciplinary research is fundamental to advancing the field. Ernst & Young in its annual recap of the biotechnology field makes the point:

> From agriculture to fine chemicals, from drug discovery to health, companies are migrating and integrating their scientific approaches and business aspirations to create broad platforms for new products and markets. Fueled by—and contributing to—developments in information technology and nanotechnology, these hybrid markets are true bellwethers of the information age, generating enormous quantities of information at multiple scales of time and space. [27]

An excellent example of a new, existing interdisciplinary research enhancement is the proposed Center for Single Molecule Biophysics at ASU. This new focus will bring together nanoscience, physics, chemistry and molecular cell biology to develop new methods and tools to study biological processes and to advance new interdisciplinary graduate training.

Pursuing interdisciplinary research is of particular importance for Arizona because it is in a position of playing catch-up in bioscience research. The more Arizona can leverage its research strengths and collaborate not only across departments in individual institutions but across institutions, the quicker the state can realize key gains.

Fortunately, Arizona research institutions display a high degree of both interdisciplinary as well as cross-institutional efforts that are actively underway today. Among the examples that have been cited throughout this report include The Arizona Center for Alzheimer's Disease Research, University of Arizona Health Science Research Consortium, the Piper Cancer Center, and the newly formed Institute of Mental Health.

It is recommended that, within each platform area for development, a specific plan to further interdisciplinary, inter-institutional collaboration be identified using incentives, shared facilities and cross-appointments, and other mechanisms.

CONCLUSION: BIOSCIENCE RESEARCH IS A KEY TARGET OF OPPORTUNITY FOR ARIZONA

The biosciences represent a key target of opportunity for Arizona. Several key core competency areas of the biosciences offer opportunities to establish technology platforms in which Arizona can become nationally prominent over the next five years and, over the next 10 years with sustained investment, can join the ranks of the top bioscience states.

Arizona has proven that it can transform itself into national research prominence and, with it, enjoy the benefits of sharing in new economic drivers from optics to electronics. In recent decades, Arizona has established itself as a national leader in key areas of natural science research, particularly astronomy, other physical sciences, and earth sciences/ecology.

[26] Jeffrey Brainard, "U.S. Agencies Look to Interdisciplinary Science," *Chronicle of Higher Education,* June 14, 2002.

[27] Brian Sager, Ernst & Young Life Sciences Strategy Consultant, "Strategic Drivers of Convergence," *Convergence: The Biotechnology Industry Report*, Millennium Edition, 2001, page 26.

If Arizona's research universities can replicate the tremendous success they have had in the natural sciences, then the state can reverse the recent period of slower growth in overall research relative to the nation that has occurred in the late 1990s.

This is a formidable challenge. The overall bioscience research growth in Arizona has not been keeping pace with the nation. Given the major growth in bioscience research both actual and expected, Arizona can reap major benefits from bioscience research. Alternatively, if the state does not position itself more strongly in the biosciences, then its overall research base may continue to fall relative to the nation as it misses out on a key driver of research growth.

Focusing on the biosciences can have a substantial impact on Arizona's research base. If Arizona in 2000 were at the national level of bioscience-to-total-research funding, it would mean an increase of nearly $150 million in research activity in Arizona, raising the state from its current ranking of 21st to 16th in the nation in overall research funding.

Arizona's Competitive Position in the Biosciences

Key Success Factors

The San Francisco Bay Area, Boston, the Baltimore/Washington region, the New York/New Jersey metro area, and San Diego are generally regarded as the nation's premier bioscience centers. An examination of the factors that have enabled these regions to succeed in growing their bioscience bases shows that they share a number of characteristics. They include

- ***Engaged universities with active leadership.*** An outstanding research university is required to become serious about the biosciences. But, it takes more than simply research stature. It requires the capability to engage industry, directly or indirectly, to convert this intellectual knowledge into economic activity. To do so requires one or more of a state's research universities committed to engage with and help build and sustain a bioscience community locally. The leadership of Arizona's universities has demonstrated a willingness to collaborate in support of developing the state's bioscience sector and is initiating policies and programs to improve technology transfer and commercialization. These are important first steps in creating the type of university-industry relationships found in other leading bioscience centers.
- ***Intensive networking across sectors and with industry.*** As many observers of high-technology clusters have noted, the most successful clusters facilitate extensive and intensive networking among technology companies and their managers and employees. In a very few leading communities like Silicon Valley, this networking has occurred naturally, with formal organizations like Joint Venture-Silicon Valley coming only later. However, in the vast majority of states and regions, such organizations need to be built from the ground up; otherwise, the desired degree, scale, and intensity of networking will not occur. Arizona does not yet have a critical mass of bioscience companies or sufficient networking and mentoring.
- ***Available capital covering all stages of the business cycle.*** Leading bioscience states share one characteristic: they are home to a venture capital community that is both oriented toward early-stage financing and committed to local investment. Having state-based venture capital funds with experience investing in bioscience companies is critical. It is also critical to have financing available for each stage of development from early-stage, proof-of-concept, and prototype development to product expansion and later-stage venture financing. While a number of Arizona-based venture funds exist, several of which are investing in bioscience companies, a gap in pre-seed/seed stage funding for bioscience companies is generally conceded.

Key Success Factors

- Engaged universities with active leadership
- Intensive networking across sectors and with industry
- Available capital covering all stages of the business cycle
- Discretionary federal or other R&D funding support
- Workforce and talent pool on which to build and sustain efforts
- Access to specialized facilities and equipment
- Stable and supportive business, tax, and regulatory policies
- Patience and a long-term perspective

- ***Discretionary federal or other R&D funding support.*** To build generic R&D assets into an effective attractor of technology investment requires leverage of substantial, ongoing, external, discretionary funding. Technology leaders like Silicon Valley, Route 128 in the Boston area, and San Diego were able to leverage decades of heavy defense contracting, while Baltimore/Washington leveraged growing congressional support of federal laboratories owned by NIH, the National Institute of Standards and Technology (NIST), and the Food and Drug Administration (FDA). In the absence of massive federal or corporate investment, most states must use state funding as a lever for acquiring strategic external investments. The premise behind the investments made in TGen and IGC is that additional federal bioscience funding will be attracted to Arizona.
- ***Workforce and talent pool on which to build and sustain efforts***. Like any knowledge-based industry, bioscience companies need a supply of qualified, trained workers. To meet the demands of newly emerging fields, new curricula and programs need to be developed by educational institutions working in close partnership with the bioscience industry. In addition to having world-class researchers, successful bioscience states and regions have an adequate supply of management, sales, marketing, and regulatory personnel experienced in the biosciences. While Arizona's universities and community colleges are producing graduates with degrees in the biosciences and bioscience-related fields, it is difficult to find managers and other workers experienced in the biosciences.
- ***Access to specialized facilities and equipment.*** Facility costs are among the most significant expenses of a new bioscience firm. These firms need access to wet lab space and specialized equipment. Since most bioscience firms initially lease space rather than purchase it, an available supply of facilities (such as privately developed multi-tenant buildings) offering space and equipment (such as incubators and accelerators) for bioscience companies is critical. Arizona lacks bioscience incubators, accelerators, and research parks and has inadequate wet-lab facilities.
- ***Stable and supportive business, tax, and regulatory policies.*** Bioscience companies need a regulatory climate and environment that encourage and support the growth and development of their industry. Tax policies that recognize the long development cycle required to bring new bioscience discoveries to the market can provide additional capital for emerging companies, as well as ensuring an even playing field in state and local tax policies between older, traditional industries and emerging industries such as the biosciences. Arizona's tax structure needs to be comprehensively reviewed to ensure that it has the incentives in place to encourage private sector bioscience investment and the growth of the industry.
- ***Patience and a long-term perspective***. One final lesson from every successful technology community is that success takes time. Silicon Valley and Route 128 trace their origins in electronics to the 1950s and in life sciences to the 1970s. Research Triangle Park represents a 50-year strategy that has only recently found its footing in the biosciences and is still working to develop full capability in the entrepreneurial sector. In contrast, Maryland and San Diego have emerged as major bioscience centers in 12 to 14 years. And, in both cases, research investments were being made for many years previously. While this may indicate that the time required to become a leading bioscience center can be shortened, it must be recognized that such development cannot be accomplished in a year or two or around a single project. It requires a long-term effort.

Table 10. Comparison of Arizona to Best Practice States and Regions on Key Success Factors

Factors of Success	Best Practice States/Regions	Arizona Situation
Engaged Universities with Active Leadership	✓ Universities are engaged in economic development and committed to technology transfer ✓ Have created vehicles for technology commercialization	✓ The leadership of Arizona's universities is committed to developing the biosciences and has entered into partnerships such as TGen ✓ Improvements have been made in technology transfer and commercial-ization, but greater investment is needed in vehicles for technology commercialization
Intensive Networking	✓ Active technology intermediary organizations provide a focal point for the state's biotechnology efforts ✓ These organizations play a critical role in networking academic, industry, government, and nonprofit groups, encouraging cross-fertilization of ideas and opportunities that lead to joint endeavors	✓ There are no active, professionally staffed industry organizations that have the ability to provide networking opportunities at the scale and intensity necessary to promote the emerging bioscience firms ✓ The state's existing bioscience cluster organizations are still in an early stage of development after several false starts
Available Capital	✓ Best practice states and regions have created programs to address the commercialization, pre-seed, and seed financing gaps to help establish and build firms ✓ Active informal angel networks investing in the biosciences ✓ Investors include private, philanthropic, and public entities	✓ A number of Arizona-based venture funds exist, several of which are investing in bioscience companies ✓ A gap in pre-seed/seed funding stage is generally conceded ✓ Limited angel networks are investing in the biosciences
Discretionary R&D Funding	✓ Every major technology region in the U.S. has received significant federal discretionary funding ✓ One or more federally designated centers exist that serve as anchors for the state or region's bioscience base	✓ Market share of NIH funding awards has decreased ✓ Limited success exists in obtaining federally designated bioscience centers ✓ Successful effort to attract IGC and TGen represents major accomplishment
Talent Pool	✓ Talent increasingly provides the discriminating variable for states and regions to build comparative advantage ✓ Educational institutions at all levels responsive to training students to meet the needs for bioscience workers at all skill levels, including scientists, technicians, and production workers	✓ Arizona graduates are in excess of bioscience jobs available ✓ Strong interdisciplinary efforts exist at universities ✓ Strong community college system is offering increased curricula in the biosciences ✓ Weak K-12 system will limit ability to produce students who will pursue bioscience careers

Table 10. Comparison of Arizona to Best Practice States and Regions on Key Success Factors (continued)

Factors of Success	Best Practice States/Regions	Arizona Situation
Specialized Facilities and Equipment	✓ Leading bioscience regions have private markets that provide facilities offering space for bioscience companies ✓ Specialized bioscience incubators and research parks are common ✓ Access to specialized facilities and equipment, such as core labs and animal facilities, is readily available	✓ Wet-lab space is insufficient ✓ No specialized bioscience research parks exist ✓ Incubator and accelerator space for bioscience companies is limited ✓ Knowledge of university equipment and facilities that could be accessed by firms is lacking
Supportive Business Climate	✓ Incentives to encourage growth of technology-driven firms through modernized economic development tool kit ✓ Tax structures generally leveled to treat technology-driven and manufacturing firms evenly ✓ Established brand name/image around technology themes	✓ Arizona has few economic development assistance programs to attract, retain, and grow bioscience firms ✓ Arizona's tax structure is not favorable for the development of a technology-based economy ✓ Arizona's affordability, regulatory environment, and access to resources are better than on either coast ✓ Arizona does not have an image or brand as a high-technology center
Patience and Long-term Perspective	✓ Building a critical mass of bioscience firms takes many years or even decades ✓ While the early technology pioneers took 25 years to develop, more recent examples such as Maryland and San Diego took 12 to 14 years to mature	✓ Arizona does not have a history of long-term state investment in technology development ✓ Development of successful partnerships to pursue IGC and TGen suggest that public and private leaders are beginning to make a long-term investment to building Arizona's bioscience base

The Battelle team also identified the strengths, weaknesses, opportunities, and threats (SWOTs) facing Arizona in its effort to position itself in the biosciences. This was accomplished through interviews, small group discussions, several focus group discussions, review of other studies, and collection of secondary data. The following section presents the findings from the SWOT analysis.

STRENGTHS

Arizona possesses an economic base in the biosciences that is small but rapidly expanding, outpacing national growth trends.

Arizona's bioscience employment base[28] has grown nearly 80 percent over the last six years, now consisting of approximately 450 establishments employing 9,100 workers. As a result, Arizona's location quotient has increased from 0.38 in 1995 to 0.48 in 2002. This is a significant increase, although Arizona remains more than 50 percent under concentrated in the biosciences than is the nation as a whole.

[28] Excludes the hospital and laboratory subsector.

More importantly, growth in the state's bioscience sector is quite diverse, with all five subsectors outpacing the nation in terms of employment increase, indicating the breadth of opportunity in the sector. In several cases, the growth has been phenomenal: organic and agricultural chemicals growth was 186.6 percent higher, and employment expansion in medical devices and instruments was 45.4 percent higher than the national average. It is important to note, however, that approximately half of the increase in employment in the organic and agricultural chemicals subsector was due to the expansion of one company.

The state and regional leadership has become more engaged in and supportive of the biosciences, best epitomized by the successful creation and recruitment of TGen and IGC.

In an unprecedented display of partnership, the State of Arizona, Maricopa County, the City of Phoenix, and numerous private and public entities have committed to investing more than $90 million to attract both TGen and IGC to locate in Phoenix. TGen will focus on applying genomic discoveries into treatments for common diseases, with an initial focus on cancer. When fully operational, TGen is expected to employ approximately 250 researchers and scientists. IGC, a nonprofit Arizona corporation, will be working to generate a major public database of gene expression in normal and cancerous human tissues. TGen and IGC are expected to be important anchors for the development of a bioscience hub in downtown Phoenix. The successful attraction of TGen and IGC has created momentum or "buzz" around the concept that the biosciences can serve as a core strength in Arizona's technology-based economy.

Arizona has a strong history of entrepreneurship, although the focus has traditionally been in services (such as real estate, tourism, retail, and related areas), not technology.

Evidence of this strong entrepreneurial culture is found in the fact that Arizona ranks extremely high in metrics that attempt to rank its level of entrepreneurial development. In the Progressive Policy Institute's *The 2002 State New Economy Index*, Arizona ranked fifth in the nation in economic dynamism, which is defined as a state's ability to foster the creation of new firms, support firms that innovate, and cultivate a culture that is epitomized by fast-growing, entrepreneurial companies. The state ranked fourth in the 1999 survey. This dynamism ranking was composed of several metrics.

- The number of jobs in "gazelle" companies (companies with annual sales revenue that have grown 20 percent or more for four straight years) as a share of total employment. In the gazelle category, Arizona ranked second in the nation in 2002, up one position from 1999.
- "Job churning," which is defined as the number of new start-ups and business failures combined as a share of all establishments. Steady growth in employment masks the constant churning of job creation and destruction, as less innovative and efficient companies downsize or go out of business and more innovative and efficient companies grow and take their place. While such turbulence increases the economic risk faced by workers, companies, and even regions, it is also a major driver of economic innovation and growth. Arizona ranked third in 2002 and ranked fifth in 1999.
- The number of initial public offerings (IPOs), a weighted measure of the value and number of IPOs of companies as a share of gross state product (GSP). In this category, Arizona ranked 18th in the nation, up from a ranking of 23rd in 1999.

It is important to note, however, that these rankings are not specific to the bioscience industry or to the technology sector. Interviews suggest that a service/real estate base, and not an emerging technology base, are driving many of the rankings.

Overall, the business environment in the State of Arizona is conducive to fostering development due, in large part, to its brisk population growth, affordability, access to resources, and proximity to California and Mexico.

Arizona's population grew 40 percent between 1990 and 2000, compared with the U.S. population, which grew by 13 percent over those 10 years. Arizona's population influx has provided access to a highly productive workforce due to the consistent in-migration of employees and the relative ease with which companies are able to recruit individuals to the state.

In addition, Arizona's affordability, regulatory environment, and access to resources are better than on either coast. For instance, the cost of energy is low due to the abundance of electrical power from the Arizona Public Service and Salt River Projects. Utility companies are also experienced in dealing with demanding technical requirements for reliability, access, redundancy, and power supply. Arizona has an extensive satellite network and other communication linkages that it can utilize for telemedicine and other outlets. Arizona, with two international airports, also has low-cost and relatively extensive air service to most major markets. Finally, Arizona also has an extensive hospitality and tourism industry with numerous meeting and conference facilities and resorts.

With regard to the bioscience industry specifically, Arizona's proximity to major markets, such as California and Mexico, is a competitive advantage. The fact that the state is close to the bioscience cluster in San Diego offers unique opportunities for Arizona's emerging bioscience activity. Also, its access to Mexico for medical production and/or assembly, as well as a potentially expanding market, will create additional opportunities. Specifically unique to Arizona is the diversity and size of its clinical population for research, patient base, clinical trials, and an extensive tissue repository.

Arizona residents and business owners consider the state to have a high quality of life in terms of cultural and recreational amenities, climate, and affordability.

Arizona offers affordable high-quality housing, and a climate, typography, park system, and cultural history that attract people who are either outdoor enthusiasts or attracted to the near-constant sunshine and warmth. Arizona's climate, in particular, is a major attraction that has led many company founders to relocate to the state.

Arizona's cost of living is attractive compared with the cost of living in many existing and emerging bioscience regions. The cost of living in Phoenix and Tucson for the last quarter of 2000 was 102.5 and 99.6, respectively (with 100 equal to the national average).[29] This compares favorably with the cost of living in San Diego (127.3); Denver (105.3); and Portland, Oregon (105.3). In addition, Arizona's personal income tax is among the lowest in the nation, ranging from 3.3 to 5 percent.

---

[29] Source: ACCRA, *Cost of Living Index, 4th Quarter 2000*, "2001 Statistical Abstract of the United States," p. 458.

In interviews with the Battelle team, company executives indicated that these factors make it is easy to retain employees.

In recent decades, Arizona has established itself as a major player in basic research primarily focused on the physical sciences and ecology, areas that may complement and assist the state in building its bioscience base in areas such as imaging, optics, and biomedical engineering.

The amount of basic research performed across the three research universities in Arizona has reached $514 million, a ranking of 21st in the nation.[30] As Arizona's basic research has grown, it has become a national leader in key areas of physical sciences, natural sciences (particularly astronomy), and earth sciences/ecology. Arizona ranks second in the nation in astronomy, seventh in earth sciences/ecology, 11th in mechanical engineering, and 12th in civil engineering.[31]

Arizona has taken significant and meaningful steps to augment its state support for bioscience research with its health research fund, Proposition 301 funding, and the voter approval to dedicate new tobacco tax revenues in part to additional research.

During the past eight years, the State of Arizona has initiated several programs to provide funding for bioscience research. In 1984, the Legislature created the Arizona Disease Control Research Commission (ADCRC) to advance research into the causes and prevention of diseases including drug discovery and development. In FY 2001 and FY 2002, ADCRC's total funding for health research was approximately $10 million. In FY 2003, total funding is expected to be about $13 million. ADCRC annually solicits research proposals from universities and private institutions. Funds are awarded through a competitive review process.

ADCRC's funding comes from tobacco tax revenues and the state's tobacco settlement fund. In November 2002, Arizona citizens approved a referendum to raise tobacco taxes by 60 cents a pack. It is estimated that the tax increase will generate an additional $151 million, 5 percent of which would go to the Health Research Fund.

In the Spring of 2001, the Board of Regents allocated funding to the public universities for new research initiatives in biotechnology. The funding was provided through the new sales tax authorized by Proposition 301, which established a Technology and Research Initiative Fund to be administered by the Board of Regents. Monies from this fund were also allocated for other initiatives in research, technology transfer, access to workforce development, a Regents Innovation Fund, and the Arizona Regents University.

A five-year budget was approved for three biotechnology initiatives, with funding for the first year totaling $13.1 million. Arizona State University was funded to establish the Arizona Biomedical Institute, with research components in bioengineering, biotechnology, cognitive diagnostics, and basic biological processes. Northern Arizona University was funded to establish the Northern Arizona Center for Biotechnology and Human Welfare, with major interdisciplinary foci that encompass a broad array of bioscience research with particular emphasis on

---

[30] National Science Foundation. *Academic R&D Expenditures*.
[31] National Science Foundation, *Academic R&D Expenditures*.

bioscience/biochemistry research. Finally, the University of Arizona was funded to develop the Institute for Biomedical Science and Biotechnology.

Arizona has a robust Community College System that is focused on meeting the workforce needs of the state's technology industries, including the biosciences; and the state's universities have strengthened their bioscience curricula.

The State of Arizona has one of the largest Community College Systems in the nation that often serves as a national model of excellence. The individual Centers for Workforce Development have developed partnerships with hundreds of existing and emerging companies to custom design and deliver training to facilitate productivity of new employees and upgrade skill sets of existing employees. The Centers also work with economic development offices in their regions to attract new employers and have provided recruitment and training assistance for hundreds of business relocations or expansions.

Recently, a Biotechnology Associate of Applied Science Degree Program was created at Mesa Community College, the only two-year biotechnology program in Arizona. The program includes courses designed to provide students with a working knowledge of the field by focusing on competency and technical expertise with state-of-the-art laboratory protocol and critical consideration of current topics in biotechnology. Numerous other community colleges throughout the state have since begun the process of offering similar programs on their campuses.

The state's universities have developed new curricula in the biosciences, many of which are interdisciplinary, such as the Biomedical Engineering Interdisciplinary Program and the Cancer Biology Graduate Interdisciplinary Program at UA and the Molecular/Cellular Biology interdisciplinary program at ASU.

WEAKNESSES

The state's existing private sector base is not heavily concentrated in the biosciences.

As shown in the economic analysis, despite the rapidity of recent employment growth, Arizona is 52 percent less concentrated in the biosciences than the United States as a whole.[32] None of the bioscience subsectors exhibit a location quotient larger than 0.78, illustrating that Arizona still has a long way to go to match the nation's level of bioscience industry presence. Of the eight states against which Arizona was benchmarked, only three—Georgia, Oregon, and Oklahoma—are less concentrated in the biosciences than Arizona. Further actions of both the private and public sectors will be needed to encourage the timely development and maturation of the Arizona bioscience sector and to find and develop key niche areas in which Arizona can ascend to national prominence.

The business focus in Arizona tends to be dominated by traditional industries and continues to rely on historic but eroding advantages such as tourism, low-cost labor, and climate. Business lobbying has tended to focus on traditional tax-break issues in the Legislature. Only recently

[32] Excludes the hospital and laboratory subsector.

have certain long-term issues, such as education and talent, been recognized as critical to business development and future success.

Arizona is perceived to have a low performing K-12 education system.

Education is widely perceived as among the most fundamental problems in Arizona in terms of providing workforce, attracting and keeping talent, and developing research strengths. In a survey of employers conduced by the Morrison Institute for Public Policy in 2001, 52 percent of the respondents indicated that talented prospective workers have reservations about locating in Arizona because of poor performing public schools. In 2000, 22 percent of Arizona's fourth graders and 24 percent of the state's eighth graders scored at or above the "proficient" level on the National Assessment of Educational Progress science test. Nationally, 28 percent of fourth graders and 30 percent of eighth graders score at or above the proficient level.[33]

The growth of Arizona's university research base has slowed in the last five years, and state support for universities has decreased.

Between FY 1995 and 2000, total academic research in Arizona grew only 16 percent, while total U.S. academic research climbed by 29 percent. This may be due, in part, to the fact that Arizona has not been investing adequately in the infrastructure needed to attract and keep the high-quality faculty and researchers most likely to attract federal and private sector R&D dollars, as documented in a recently released Arizona Board of Regents study. Some individuals interviewed suggested that the state is "starving" or "underinvesting" in its public institutions of higher education. Lack of funding to offer competitive salaries and build needed lab facilities, along with some regional competition among the institutions, has caused the universities' research efforts to suffer.

In the biosciences, Arizona's university research efforts have been lagging the nation.

The biosciences account for $229 million of university research in Arizona, or 44 percent of the university research base in the state. This falls far short of the national average of 57 percent that the biosciences compose of total university research. Not surprisingly then, Arizona's national ranking in university-based biosciences research is 27th in the nation, compared with its overall research ranking of 21st. Furthermore, total bioscience research grew only 27 percent in Arizona from 1996 to 2000, compared with 36 percent for the nation, meaning Arizona is losing market share of national research dollars.

NIH funding—the gold standard of biomedical research funding, which includes funding to non-university entities—is also lagging in the state of Arizona. For FY 2001, Arizona received $117 million in NIH research funding, placing the state 27th in the nation. Growth in NIH funding from 1997 to 2001 stood at 38.4 percent in Arizona, compared with 45.3 percent for the nation.

The University of Arizona dominates basic bioscience research in the state, yet is not among the top universities in the nation in bioscience research. The University of Arizona accounts for nearly $9 out of every $10 expended upon university bioscience research in Arizona, and $8 out

[33] U.S. Department of Education, Office of Educational Improvement, National Center for Education Statistics. *The Nation's Report Card: State Science 2000, Report for Arizona,* Washington, DC, 2001.

of every $10 of NIH-funded research as well. Yet, the University of Arizona ranks only 50th in NIH funding across the United States, and 29th in total university bioscience R&D expenditures.

Battelle's experience with life science centers throughout the United States shows that, at the present time, the most critical ingredients to strengthening the research enterprise are adequate facilities and the ability to recruit and retain outstanding research talent. Currently, academic health and higher education institutions are finding that those places that have sufficient and modern research facilities are the ones that can attract bioscience talent, and that talent, in turn, attracts federal and industry research dollars. This is a much different paradigm than that of the past, but one that many regions and states are embracing. Arizona's universities lack the physical infrastructure to adequately compete in the biosciences.

Arizona's universities do not have a strong tradition of commercializing technology, encouraging entrepreneurship among faculty, or partnering with local companies.

While Arizona's universities have begun to encourage partnering with industry and technology transfer and commercialization by their faculty, these efforts are relatively new. The Arizona Board of Regents has developed and issued new policies; but, the infrastructure at each university has not been totally ramped up. The ASU Office of Technology Licensing and Collaboration, which also manages intellectual property (IP) for NAU, has been active for only about five or six years. The UA technology transfer office has been in transition for three years, recently recruiting a new director. Although new programs, such as a gap-funding program being put in place at ASU funded with Proposition 301 monies, are being initiated, the technology transfer offices are working with very limited resources.

Researchers interviewed indicated that faculty are not provided sufficient incentives to partner with industry or otherwise spin off firms from their research. One essential issue that needs to be addressed is that the Arizona Constitution prohibits the universities from owning stock in private firms. While there may be ways to address this administratively, limited steps have been taken to date. This provision can make it difficult for the universities to license IP to a start-up company that does not have the cash flow to pay a license fee or royalty. ASU is exploring the possibility of establishing a foundation that would be able to hold equity.

Interviews with business executives indicated that Arizona companies are not partnering with the state's research institutions to the extent that they might, due in part to limited staffing and dedicated resources to support commercialization activities or to encourage greater interaction between university researchers and industry. The reluctance of some companies to collaborate with the universities may be due in part to past experiences and the perception that the universities are not interested in working with the companies.

The state lacks the necessary ingredients for a bioscience entrepreneurial culture, including the lack of a critical mass of bioscience firms with strong ties to academic researchers, difficulty in attracting entrepreneurial technology managers and bioscience management staff, and limited networking opportunities for such firms among themselves and with academia.

Despite Arizona's reputation as an entrepreneurial hot spot, few biotechnology or medical device start-up firms exist in Arizona. Bioscience industry growth depends heavily upon the transfer of technology from local universities and research institutes to local businesses. Despite some excellent research, the small bioscience industry that has grown in Arizona is not generally well connected with the universities. Many of the state's emerging bioscience companies did not get their start with technologies developed at the state universities, but are developing technology internally or licensed from other sources. Since research and development is crucial to competitiveness in this industry, connecting with and leveraging the wealth of knowledge and technology within these universities is one key to its future growth.

Also, entrepreneurs need to be connected to assets. Entrepreneurs need access to money; management advice; partners; networking/information exchange forums; education through seminars, workshops, and training programs; and general support services. Networks that help entrepreneurs make these connections are vital to the success of new companies. However, no active, professionally staffed industry organizations have the ability to provide networking opportunities at the scale and intensity necessary to promote the emerging bioscience firms. The state's existing bioscience clusters are still in an early stage of development after several false starts. There is no single entity to help connect the emerging bioscience industry with the assets necessary to succeed.

Arizona lacks a critical mass of bioscience firms, making it difficult to attract senior life-science entrepreneurial technology managers (referred to as "serial technology entrepreneurs") and senior sales and marketing and regulatory managers to the state. Furthermore, entrepreneurial role models that can help demonstrate the potential for bioscience ventures and encourage others to become entrepreneurs are limited.

There is a lack of bioscience-focused venture capital and angel investors in Arizona, most particularly to address the commercial and pre-seed/seed stages of the life cycle of bioscience firms.

Access to early-stage risk capital is a critical factor in building a bioscience-driven economy. One characteristic shared by leading bioscience states is that they are home to a venture capital community committed to early-stage local investment. These states also have networks of successful entrepreneurs who act as angel investors, willing to invest in very early stage start-up companies. Building a base of angel investors and pre-seed/seed venture capital funds able and willing to invest in emerging companies is a challenge for many states. Available financing also is critical for each stage of development from early-stage, proof-of-concept, and prototype development to venture financing.

In a survey of 400 Arizona entrepreneurs conducted in 2002, 71 percent of the entrepreneurs who were looking for capital said the process was either difficult (21 percent) or very difficult (50 percent).[34] In addition, respondents indicated that there is "definitely a shortage of capital for early stage companies."

Arizona companies have had difficulty acquiring venture capital dollars. The Progressive Policy Institute ranked Arizona 24th in venture capital invested as a percentage of GSP, a decline from 13th place in 1999. Over the last five years for which venture capital data are available, San Diego, for example, secured more than $2 billion in bioscience-related venture capital, while Arizona bioscience companies received only $122.7 million. It is also important to note that

[34] Dee Power and Brian Hull. *Arizona Entrepreneurs: Critical Factors to Success*, April 2002.

nearly all of the venture capital deals in the state were focused on the medical and healthcare subsectors, rather than biotechnology. The result is that Arizona academicians have started their firms in San Diego, rather than within the state.

Few funds, regardless of their stage of investment, are focused on the biosciences; although, this is changing, with several new funds being started that are investing in bioscience firms. State and local pension funds have not invested significantly in venture capital. Similarly, angel investors tend to focus on information technology as well as the staples of the region's historic economic base in real estate, travel and tourism, and retail. Angel networks appear to be few in number and nonexistent, even informally, in the bioscience field.

The state has few economic development assistance programs to attract, retain, and grow bioscience firms.

Unlike many other states, Arizona has few programs, with the exception of the state's workforce development programs, that can be used to assist companies interested in expanding or relocating to Arizona. The one source of discretionary funding is the budget of the Community and Economic Development Commission (CEDC), which receives a portion of the state's lottery revenue. CEDC's allocation in FY 2002 is expected to be approximately $2 million. During the last several years, however, the CEDC funds have been used to help address gaps in the overall Department of Commerce budget.

In contrast, other states offer a comprehensive array of programs and services to support the creation and growth of technology businesses. In addition, those states support private-public partnerships that offer initiatives addressing the specific needs of biotechnology companies, including providing access to seed and early-stage capital, subsidizing the cost of life-science facilities, and providing in-depth planning and management assistance to entrepreneurs and start-up companies. To compete successfully, Arizona needs to develop policies and private-sector-driven, "gap-filling" programs that will meet the needs of bioscience companies at all stages of their development.

Arizona's tax structure is not favorable for the development of a technology-based economy.

According to data compiled by the Center for Business Research at Arizona State University, Arizona's business tax burden is the 14th highest in the nation, while its household tax burden is 32nd in the nation.[35] This is the result of a strategy aimed at attracting retirees and tourists to the state, which is not going to position Arizona to grow a knowledge-based economy with robust technology sectors including the biosciences.

Arizona has no specific tax incentives for technology firms; however, the state does have an R&D tax credit that allows a taxpayer to receive a maximum credit of $500,000 on research carried out in Arizona. The credit also covers research conducted at an Arizona university and paid for the taxpayer. The credit may be carried forward for 15 years. The credit, however, will expire in 2003 if not reauthorized by the Legislature.

---

[35] Morrison Institute for Public Policy. *Arizona Policy Choices: Five Shoes Waiting to Drop on Arizona's Future.* October 2002, p. 44.

The state is facing severe budget constraints that will make it difficult to invest at the level required to position Arizona as a strong competitor in the biosciences.

For FY 2002, Arizona is facing a significant budget shortfall; and the predictions for FY 2003 are no better. In addition, voter-passed ballot measures dictating state revenue allocations have steadily reduced state flexibility in the use of revenues. Between 1990 and 2000, Arizona voters enacted nine separate ballot measures that directed that funds be used for specific purposes.[36]

As a result of the state's budget situation, Arizona's higher education institutions have sustained budget cuts that seriously affect the universities' ability to attract and retain faculty and to build the facilities needed to remain competitive.

Active public-sector leadership will be needed to ensure support for higher education and to support recent initiatives, including TGen and IGC, as well as to support any new investments to further develop the state's bioscience sector. The coalition of private and public organizations that have succeeded in landing IGC and TGen has stretched the limits of its funding sources. Furthermore, term limits may make it difficult to have long-term champions in state government. The current budget crisis is an immediate threat to enabling Arizona to secure the level of public investments, including higher education research facilities, equipment and instruments, wet-lab space, and faculty recruitment, that will be required to compete with other states and regions seeking to grow their bioscience sectors.

Business service providers are not as strongly specialized in the biosciences as other competitor states building bioscience bases.

While the interest of the state's business service professionals is high, there is insufficient expertise to serve bioscience entrepreneurs. Arizona's service providers have historically served larger corporations and other industries, such as retail, real estate, and the travel and tourism industry. Unlike other regions of the United States, few business service providers in Arizona provide reduced rate or pro bono services to emerging bioscience firms.

Arizona does not have an image or brand as a high-technology center.

Arizona is not seen as a bioscience center. The perception by many is that companies locate to Arizona because of the lower cost labor pool, not because of technology or innovation capabilities. Business and community leaders interviewed indicated that Arizona seeks to promote itself as a low-cost location. Marketing focuses on the availability of inexpensive land, low-cost labor, affordable housing, and low taxes. However, such factors will not attract technology firms or lead to the creation of an innovative economy. This image of Arizona must change if the state is going to successfully cultivate a bioscience cluster.

Arizona lacks a skilled workforce to serve the bioscience industry.

In the old economy, states prospered by having workers who were skilled with their hands and could reliably work in repetitive and sometimes physically demanding jobs. In the new economy, states will prosper if their workers are good with their minds, because knowledge-

[36] Morrison Institute for Public Policy. *Arizona Policy Choices: Five Shoes Waiting to Drop on Arizona's Future.* October 2002, p. 40.

based jobs are driving the new economy. However, according to the U.S. Census Bureau, less than 30 percent of the Arizona population in 2000 had attained an associate’s degree or higher, evidence that the state’s citizenry is not prepared for the technically demanding jobs of the new economy. In addition, Arizona ranks 32nd in the nation in terms of the number of scientists and engineers as a percentage of the workforce in 2002, according to a report by the Progressive Policy Institute.

These data are consistent with the findings from the interviews. Business leaders expressed the difficulty in finding managers with technical backgrounds and skilled workers in technological fields. Lack of a critical mass of firms has also made it difficult to attract technical talent to the state. Business leaders also expressed the difficulty in attracting the very best and brightest since alternative opportunities are limited in the bioscience field, and issues of trailing spouses are often a concern.

There is insufficient wet-lab space, both for research at the universities as well as on the commercial market, for firms to start up, expand, and grow.

Bioscience companies need specialized wet-lab space with enhanced air-handling and sterility requirements. Typically, these facilities are not readily available in commercial or light manufacturing buildings and are very expensive to construct or add to existing facilities. A basic, no-frills, wet-lab tenant improvement can add up to $100 per square foot or more in build-out costs; and more specialized wet-lab space for pilot production can be as much as hundreds of dollars per square foot.

The availability of specialized lab space required to develop a critical mass of bioscience companies has become a concern across Arizona. Currently, there is a lack of wet-lab space at the universities for research, as well as in the private market for companies. In particular, there is a lack of wet-lab research park space that is either in close proximity to a university or has the option for multitenant accessibility.

The University of Arizona Science and Technology Park, which has been quite successful and is currently full, is a distance from the university and has no university laboratories associated with it. There is ongoing discussion, however, regarding the development of a new research park in Tucson that would be focused on the bioscience industry and would be located in closer proximity to the university. In addition, The Tucson Technology Incubator has recently expanded to a second site. The new site, in the former Ventana Medical Systems building, offers wet and dry labs for start-up companies.

In Phoenix the research park is located close to the university; but, its tenants are composed primarily of very large companies. The park has not focused particularly on start-up and emerging companies. The research park has been quite successful and is currently full. There are no incubators currently in Phoenix; thus, emerging biotechnology companies do not have ready wet-lab space at their disposal.

OPPORTUNITIES

Arizona's existing and emerging strengths in electronics, information, optics, and materials represent an advantage for its efforts in the biosciences. These areas are increasingly converging with the biosciences, resulting in new technologies and giving the state a niche-market opportunity around technology convergence.

During the past two decades, the bioscience sector has become one of the fastest growing and most dynamic of the world economy, with the United States a world leader in the field. The benefits that would accrue to the State of Arizona from developing the biosciences include: substantial expansion of employment and income; abundant, secure, and relatively high-paying employment opportunities; improved economic stability over time, derived from the diversity of the bioscience sector; and a focus for continuing economic development.

The trend toward convergence of technologies in electronics, information, optics, materials, and the biosciences creates a potential competitive advantage for Arizona. In addition, the existence of a strong information technology cluster in the state could provide a nucleus for achieving needed critical mass in the biosciences. Experts widely agree that these areas will converge, thereby producing a new generation of technological products that embody elements of all the fields. The application of electronics, optics, and materials to biotechnology products has been evolving rapidly; and the convergence of the biosciences and information technology has led to the emergence of companies bridging the health care and Internet economies. Arizona is well positioned to benefit from these trends.

Federal funding for life science R&D is expanding dramatically. Arizona has an opportunity to capture a significant share of this R&D and must continue to do so if its research institutions are to play major roles as research engines of Arizona's future economy.

The biosciences represent a target of opportunity for Arizona. If Arizona's research universities can replicate the tremendous success they have had in the physical sciences, then it can possibly reverse the recent period of slower growth in funding that has occurred in the late 1990s. To this end, the state's universities have devoted a large portion of R&D funding to improve expertise in the bioscience industry.

Currently, however, the overall bioscience research growth in Arizona is not keeping pace with the nation. Arizona can reap major benefits from bioscience research if it can capture its piece of the national pie. Alternatively, if the state does not position itself more strongly in the bio-sciences, then its overall research base may continue to fall, relative to the nation, as it misses out on a key driver of research growth.

Capturing a percentage of this increase in federal life-science R&D funding would enable Arizona to move into the top tier of bioscience states. If Arizona in 2000 were at the national level of bioscience-to-total-research funding, it would mean an increase of nearly $150 million in research activity in Arizona, raising the state from 21st to 16th in the nation in overall research funding. However, in order to compete, the state's universities and research institutions need state-of-the-art instrumentation and laboratories to conduct the research and to attract the quality of researchers and faculty that compete successfully for NIH funding.

Arizona can build on its strong base of research institutions and medical centers to further develop excellence in bioscience research and development.

Medical or health research institutions and research universities are the most essential antecedents to growth of a bioscience industry. By building partnerships and collaborations among Arizona's research institutions, Arizona will be able to further develop an excellence in bioscience research and development. For instance, the newly created Arizona Biomedical Institute at ASU and the Institute for Biomedical Science and Biotechnology at the UA are leveraging the assets within each university, as well as the many other research resources within the state, to create a strong base in biotechnology and to work toward solutions to the world's health needs. TGen is envisioned as an independent, world-class research institution that will involve universities, the private sector, the scientific community, and economic development organizations throughout Arizona.

These partnerships within the bioscience field must continue to be fostered. Excellent research emerging from the state's universities and private research institutions, as well as interactions and joint appointment arrangements that serve to integrate the various institutions, are seen as potentially powerful contributors to economic growth in the future.

There is an opportunity to promote greater focus on translational research as a unique niche in Arizona with supporting interdisciplinary curricula.

While many basic research discoveries can offer the platform for launching new start-up companies, significant further development and clinical research needs to be undertaken to enable the research discovery to impact clinical care and, in essence, be of commercial value. This emphasis on supporting translational research is growing across Arizona's university research drivers, as the research institutions move toward more active clinical research and clinical trial programs. A large, permanent population of elderly residents, which constitutes an excellent clinical population, in addition to the arid climate of the state that provides special opportunities for clinical testing under dry-climate conditions, provides Arizona with a unique competitive position. Arizona is already conducting a significant amount of activity in clinical trials and has the potential for additional clinical trial activities, both in biotechnology and medical devices.

Arizona needs to take greater advantage of the region's talent pool in the biosciences.

The state's institutions of higher education and others are graduating a large number of undergraduate and graduate students in a wide range of bioscience fields. Many of these graduates might stay in Arizona after graduation if there were sufficient private-sector and nonprofit job opportunities for them. To the extent more firms are created and existing firms and organizations expand, the state can capture a greater share of this student pool to build its future technology-driven economy. Encouraging interdisciplinary programs and curricula can help position the state with a talent pool that can help grow the biosciences industry.

By putting in place the matchmaking services and support, a critical mass of bioscience firms can be formed.

Arizona’s primary challenge is to build a critical mass of firms, which requires quality, cutting-edge research; mechanisms and support for commercialization; and entrepreneurs ready and capable of applying the research to cutting-edge products and processes that succeed in the marketplace. Arizona needs to expand its entrepreneurial support system to position and assist these biotechnology entrepreneurs, in ways ranging from mentoring to access to capital, providing an expanded scale and intensity of networking, supporting commercialization, and attracting experienced serial technology entrepreneurial managers. One way for Arizona to do this is to capitalize on the management expertise of the large number of retired executives who live part-time in Arizona, a unique asset to the state. In addition, regularly scheduled bioscience industry-oriented events are seen as necessary, both for achieving greater integration and critical mass in the bioscience industry and for ensuring that Arizona becomes visible on the national and international maps of bioscience industry concentrations.

Growing commitment to technology commercialization is found among the state’s research universities.

While a lack of focus on commercialization has been a weakness in the past, recent undertakings indicate that Arizona’s research institutions are increasing their commitment to technology commercialization and looking for ways to strengthen their technology transfer capabilities.

Arizona’s Board of Regents approved revisions to the technology transfer policies to be implemented at all three public universities. These revisions go a long way toward enabling the research and development occurring within academic institutions to benefit local businesses and also encouraging university faculty to start their own ventures based on their research. Additional incentives are needed to encourage faculty to work on industry problems and to demonstrate that such research results in comparable peer-reviewed quality research as supported by the federal government.

The state’s investments in TGen/IGC could be leveraged to create and enhance partnerships with bioscience companies.

Arizona’s public and private leaders are committed to the development of a world-class genomics institute, as evidenced by their commitment to develop TGen and to attract IGC. Financial and other contributions of approximately $90 million have been committed to support TGen in its first five years of operation. The City of Phoenix will design, build, and finance TGen headquarters at a cost of up to $21 million. The city has agreed to lease the building to TGen for 30 years.

TGen’s mission is to “help translate scientific discoveries into diagnostics, treatments, and cures that improve quality of life.” Initially, TGen will have three main components: research programs, scientific cores, and administrative infrastructure. As TGen and IGC develop, there will be opportunities to leverage the research conducted to launch new ventures and commercialize new products.

Arizona is at an opportune time in its history to initiate bold action for long-term economic prosperity.

The state is at a turning point. As Arizona works its way out of the current recession emboldened by greater collaboration among regional organizations, it is confronted with a choice. It can either continue down the economic development path that has brought about positive growth and commit to building on its strengths by making substantive changes in its investment policies, or it can revert to its previous hands-off policy and lack of investing in the future growth and development of the state's economy. The will to act now has reached a critical mass. Both business and government leaders recognize that it is time to work together in unprecedented unity to make the needed investments and implement a new comprehensive economic development plan, including an increased role for higher education. This momentum must be carried forward under a strategic plan of activity and investments.

Arizona's proximity to other markets provides the state with a unique comparative advantage.

Proximity to California's centers of biotechnology research and development places Arizona in a unique position. Arizona serves as a less expensive alternative to California for manufacturers to locate their operations. Arizona is also a net exporter of electrical power and, in that regard, is an appealing location for power-strapped companies in California. Arizona's cost of living is indexed close to or below the national average, meaning an appealing location for businesses and future workers.

In addition, Arizona's location relative to Mexico provides both increased competition for those operations engaged in labor-intensive manufacturing and opportunity for those wanting to take advantage of less expensive labor partnerships. As the competition becomes more intense in the global marketplace, American companies are partnering with offshore manufacturing operations to take advantage of global markets and labor prices. The proximity of Arizona to Mexico, and the North American Free Trade Agreement (NAFTA), present opportunities to capitalize on the low cost of labor for more labor-intensive aspects of the business.

There are several possibilities for creating a bioscience corridor, if the appropriate infrastructure can be developed.

Initially, it may be possible to create an Arizona Corridor encompassing Flagstaff-Phoenix-Tucson. By networking the existing bioscience firms in these regions, it may be possible to create more of a critical mass of bioscience companies as each region independently has a fairly small bioscience sector. Over the longer term, it may be possible to link Arizona's bioscience companies with partners in other developed and emerging bioscience regions, such as San Diego, to create a Southwest corridor. To create a bioscience corridor will require a heightened role for research parks and incubators in encouraging bioscience industry development, particularly with regard to encouraging new start-up firms and providing linkages among the universities, university researchers, private firms, and other sectors of the community.

THREATS

Other states are aggressively pursuing life science development.

While Arizona has invested significant resources to attract and support the development of TGen/IGC, other states—such as Michigan, North Carolina, Maryland, Georgia, and Pennsylvania—are investing aggressively in a comprehensive range of bioscience programs to promote research and commercialization. A variety of states are aggressively pursuing bioscience development strategies, including strengthening research, increasing university-industry collaborations, and beefing up their business development support.

Examples of bioscience investments include the following:

- California is investing $100 million in a bioengineering and biotechnology institute and $500 million in pension funds toward the California Biotechnology Program.
- Georgia has invested more than $300 million over a 10-year period to build core research facilities and to attract Eminent Scholars, the majority of whom are in the life sciences, and has created a $1 billion Georgia Cancer Coalition that is designed to make Georgia a national leader in cancer prevention, treatment, and research.
- Texas appropriated $800 million for seven new or expanded health science research centers.

Arizona will have to invest significant resources in the biosciences just to stay even with these states, let alone surpass their efforts.

Other universities are pursuing the biosciences as a key area of focus for their future.

Universities throughout the United States and abroad are giving increased focus to the biosciences. Whether it is Indiana University and its recent receipt of a $105 million foundation grant to build its genomics and bioinformatics capabilities or efforts in California, Maryland, New York, Georgia, and elsewhere, the competition among universities for talent is becoming intense. Those universities that can offer start-up packages, facilities, equipment, and talent are the ones most likely to succeed in their visions. It is an issue of people; attitudes; funding for facilities, equipment, and support staff; and the terms and conditions for intellectual property development and licensing that can make the difference among institutions that become major players in the biosciences.

Lack of early-stage equity may deter entrepreneurial start-ups from starting or growing in the state.

Many high commercial value technologies reside in diverse bioscience communities such as Arizona. But, the lack of sufficient risk capital, coupled with the draw of established regions in providing venture financing, senior executives, and pools of scientific talent, threatens to take the most promising technologies and emerging businesses out of emerging regions. Available financing is critical for each stage of development from early-stage, proof-of-concept, and prototype development to venture financing. Leading bioscience regions have access to the following types of capital:

- ***Commercialization funding,*** which can be used to assess and undertake a review of the commercial potential of completed R&D. This assessment must be done before a business can be spun off, and may include prototype development, reduction-to-practice exploration, and other steps.
- ***Pre-seed and seed funding,*** *i.e*. financing to support very early stage start-up companies.
- ***Venture financing***, which is the capital needed prior to IPO. Given the long time frame required for the regulatory review process that must be completed before bioscience companies can introduce products in the marketplace, bioscience firms will often require multiple rounds of venture financing.

If no pre-seed and commercialization funds are available early in the life cycle of bioscience firms, they may be established and grown elsewhere.

Lack of support for Arizona's emerging bioscience companies may result in their decision to move out of the state.

If bioscience companies in Arizona cannot find managers and senior professionals experienced in the biosciences; venture capital funds whose investment portfolio includes life science companies; the legal, accounting, regulatory, and other support service organizations familiar with the needs of bioscience firms; and the specialized facilities required to grow their companies, they may consider relocating to a region where these services are available. In addition, if the state is unable to match the development assistance and incentives that other communities are willing to offer to bioscience companies to entice them to locate in the state or community, emerging companies may be lost to Arizona.

Arizona leaders must increase their knowledge and commitment to the biosciences if it is to become a key driver of the region's economic future.

With the unprecedented development of IGC and TGen, some feel that potentially unrealistic short-term expectations have developed, which may lead to a loss of public interest, disillusionment, or public backlash against investment in the biosciences if IGC and TGen do not create tangible, almost instantaneous, economic development success stories. Arizona must increase its efforts to educate and communicate with private and public leadership on the role of the biosciences in the state's overall economic future. Developing a critical mass will require that all the drivers work together strategically in collaborative relationships. This is particularly imperative as the state faces a severe budget crisis and the allocation of discretionary dollars is very tight.

SUMMARY

Arizona has a number of strengths from which to position itself as a bioscience-driven economy; but, the state also has a number of weaknesses that must be addressed if the state is to achieve its goal of becoming a center of the biosciences. First and foremost, Arizona must build a critical mass of bioscience companies through firm creation, attraction, and research-base development.

The state possesses an economic base in the biosciences that is small but rapidly expanding, outpacing national growth trends. It also has a strong entrepreneurial culture and a history of entrepreneurship, although primarily in service-related industries due in large part to the lack of risk capital available for technology firms. Arizona also has already invested funds through Proposition 301 and TGen/IGC to develop its research base in the biosciences; but, these initiatives must now be leveraged and connected to allow for maximum economic development impact.

Arizona is faced with the opportunity to focus on the convergence of technologies and markets that have the potential to translate Arizona's emergent industries and overall economic vitality into enduring economic strengths. The impact of focusing Arizona's research base on the biosciences can be substantial. But, even more importantly, by putting in place the matchmaking services and entrepreneurial support systems, a critical mass of bioscience firms can be formed. Arizona is at an opportune time in its history to initiate bold action for long-term economic prosperity.

Vision and Mission

VISION

With strong public-private leadership and long-term commitment on the part of Arizona’s research institutions, business and philanthropic communities, and state and local government, Arizona can achieve the following vision by the year 2012:

> ***Arizona is a leading southwestern state in selective bioscience sectors, built around world-class research, clinical excellence, and a growing base of cutting-edge enterprises and supporting firms and organizations.***

MISSION

To achieve this vision, Arizona must approach its future in the biosciences by

- *Further investing in and building Arizona’s world-class research and clinical and product excellence around selective bioscience sectors. The goal is to have Arizona’s growth rate in NIH research funding comparable to that of the top 10 states in the nation by 2007.*
- *Putting in place mechanisms, programs, and incentives that encourage research to be turned into products, processes, and wealth generation for the state and its citizens. Vehicles must be in place to accelerate the ability to “mine” a growing research and development base for commercial and technological development.*
- *Mobilizing public and private leadership and increasing citizen knowledge and understanding of the biosciences and its impact on health and safety, teaching and research, and economic development (bed, bench, and classroom).*
- *Building “trees of talent” by encouraging scientific and technical talent to be developed and retained in the state.*

Situational Analysis

It will likely take a decade or more for Arizona to show significant progress in achieving its bioscience vision and in building world-class research in selective fields or platforms and to realize the full potential that the biosciences have to help diversify Arizona's economy. Progress will be faster and scale reached sooner by focusing the state's private and public efforts on selective fields and areas, as identified in the "Core Competency" section of this report. Focusing resources, mobilizing private and public partnerships, and having patience and a long-term commitment are critical ways to support and sustain regional and state economies in the biosciences, as demonstrated by states such as Maryland and regions such as San Diego that have grown their bioscience clusters during the 1980s and 1990s. *While Arizona is a relative latecomer to the biosciences, it is not too late for Arizona to seek a role in the biosciences, provided that it is selective, focused, and committed to this effort.*

Arizona has relatively few biotechnology firms; but, when "biosciences" is defined (as in this report) to include drugs and pharmaceuticals, medical devices, and agricultural biotechnology, it becomes apparent that the state has both strengths and historic antecedents on which to build.

CHALLENGES

- **Strengthening its bioscience research base.** Arizona must increase its market share of federal, particularly NIH, awards and focus research efforts around key technology platforms in which it can achieve a comparative advantage and build excellence.
- **Achieving higher education research excellence**. Arizona must invest in its higher education institutions to attract leading researchers and faculty in the biosciences.
- **Addressing technology commercialization and developing a critical mass of bioscience companies.** Arizona must address the key short-term gaps that slow both the ramp-up to a critical mass of bioscience firms and expansion of existing firms in areas such as drug development, devices, and biotechnology research and development.
- **Mobilizing public and private sector leadership and improving citizen knowledge and understanding of the biosciences and their impact on both economic development and the health of Arizona's citizens.** Successful implementation of this Roadmap will require a committed strategic leadership alliance of private, public, philanthropic, and capital sources willing to support, on a long-term basis, implementation of this set of strategies.

Strengthening the Bioscience Research Infrastructure

An absolute prerequisite for building a specialized, world-class bioscience economy is having a significant base of bioscience research funding. With more than $200 million already being expended annually by Arizona's public research universities, the state has the opportunity to further build strengths in selective fields. But, to do so will require additional one-time and ongoing investments in bioscience research and development.

While the federal government has nearly completed its efforts to double the NIH research budget, Arizona's share of total NIH funds flowing into the state has decreased in percentage of national funds over the last five years. Arizona must immediately begin to reverse its recent course of losing its share of NIH awards. The competition for such funding may actually increase as additional bioscience research facilities are completed and occupied elsewhere in the country and as the states use tobacco settlement proceeds to further improve their competitiveness.

Achieving Higher Education Research Excellence

Arizona is in a "catch-up" situation. It has been lagging in the biosciences and cannot afford to lag much longer. If Arizona continues to lag, it faces the risk of abdicating excellence in the biosciences to other states and regions, even in areas where that state has existing or emerging strengths. Higher education drives where regional and state competitiveness will lie in many segments of the bioscience industry, although not all. It is critical, therefore, that a state's public universities have sufficient facilities, laboratories, and equipment, and can retain and attract the leading or future "stars" in the biosciences. Focusing research efforts around key technology platforms where Arizona can achieve a comparative advantage and build excellence is one way to focus limited resources. The current paradigm in building a bioscience research base is as follows: provide sufficient funds for facilities; staff these facilities; and the researchers, in turn, will attract the funding, particularly federal funds.

Addressing Technology Commercialization and Building a Critical Mass of Bioscience Firm

While a strong research base is particularly important and a prerequisite to forming firms and diversifying a state's economy, it is not sufficient. What also must be in place is an entrepreneurial culture that encourages start-ups to form and grow; that supports their growth through business and other expertise; that finances their development and expansion through equity capital markets; and that offers a sufficient talent pool of experienced technicians and scientists, serial entrepreneurial managers, and regulatory and marketing experts.

Mobilizing Private and Public Leadership and Increasing Knowledge and Understanding of the Biosciences

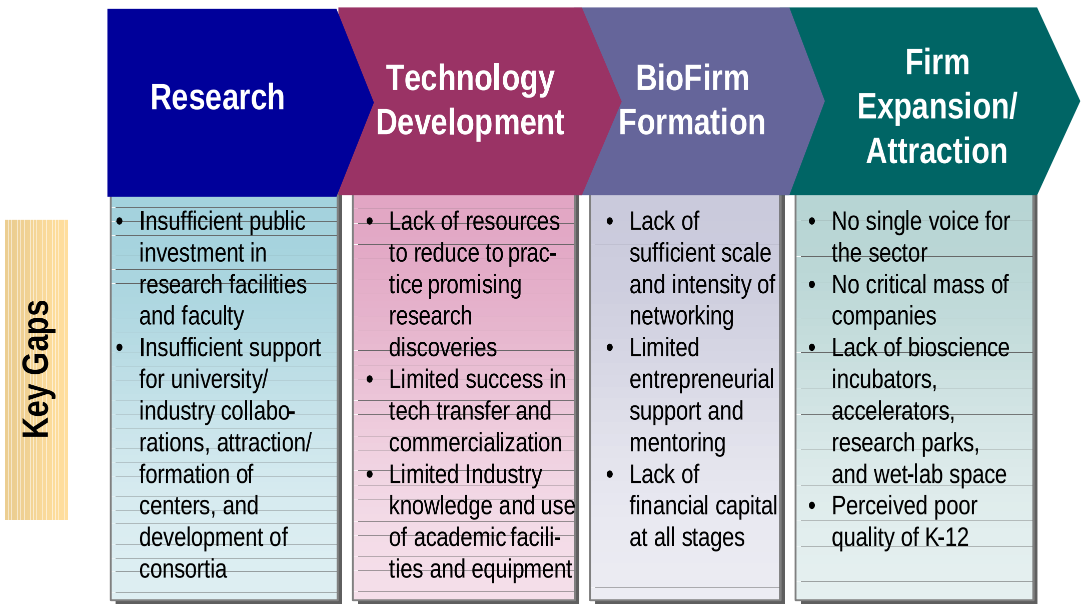
The state's current efforts remain fragmented and disorganized in the biosciences. Industry leadership is divided among multiple organizations. Connectivity with higher education varies among industry segments. Great differences exist among the state's public universities in their management of intellectual property and its commercialization. While entrepreneurship in general is strong in the state, it has not been strong among individuals with bioscience talents.

Because of the need to sustain efforts to build a regional or state bioscience base over the long term, committed leaders, i.e., champions, must step forward in the state to help lead efforts to address barriers and gaps, secure research and other funds, and market and sell Arizona as a state where biosciences is good business. A committed strategic leadership alliance of private, public, philanthropic, and capital sources must be built to ensure that this Roadmap and its proposed strategies are implemented.

GAP ANALYSIS

The economic and gap analysis identified a range of issues that must be addressed, concurrently with efforts to build a strong bioscience research infrastructure, to turn this research into technology and realize the benefits commercialized in bioscience-related products and processes in the state, the nation, and the world. Areas such as the talent pool for the biosciences, capital gaps to finance and develop bioscience firms, space needs of such firms, networking and building an entrepreneurial culture, and educating the public and citizenry on the biosciences must be addressed as part of this Roadmap Alliance. Figure 12 identifies key gaps that must be addressed to grow Arizona’s bioscience base.

Figure 12. Arizona’s Key Gaps Along the Life Science Development Continuum



The following section proposes strategies and actions to fill these gaps.

Strategies and Actions

For biosciences to emerge as a major base of Arizona's future economy, the state must simultaneously address both strengthening research drivers and dealing with important technology commercialization issues. Four strategies are proposed to develop Arizona's bioscience research base and build a critical mass of bioscience companies.

- **Strategy One***:* *Build the state's research infrastructure of outstanding talent and modern facilities and equipment around selective technology platforms and core competencies.*
- **Strategy Two:** *Build a critical mass of bioscience firms by increasing the birthrate and reducing the death rate of Arizona's bioscience firms and encouraging the commercialization of research discoveries.*
- **Strategy Three:** *Offer a business climate and environment that supports, sustains, and encourages the growth of bioscience enterprises, small and large, to start, expand, and remain in Arizona.*
- **Strategy Four:** *Encourage the state's citizens to become a more informed citizenry in the biosciences and encourage young people to explore and pursue scientific and technical careers.*

These four strategies, and the proposed 19 actions they encompass, are outlined in Table 11, followed by narrative detail in the ensuing pages. Implementation time for most of these strategies and actions is anticipated as a five-year period, with some continuing for as long as 10 years. *Immediate* priorities should be undertaken as soon as possible, *short-term* priorities should be undertaken in one to three years, *mid-term* priorities should be implemented in the three- to five-year time period, and *long-term* in the five- to 10 year time period.

Table 11. Summary of Proposed Strategies and Actions for the Arizona Bioscience Roadmap

Strategy	Action	Priority
Strategy One: Build the state's research infrastructure of outstanding talent and modern facilities and equipment around selective technology platforms and core competencies.	Establish a statewide fund (the Arizona Bioscience Research Enhancement Fund) to enhance bioscience research	Immediate
	Stimulate research collaboration among universities/hospitals/other research organizations by creating consortia, centers, and institutes in bioscience platform areas and related engineering/information technology areas	Immediate to Mid-term
	Establish a Bioscience Matching Challenge Program to connect industry and researchers and to encourage university-industry partnerships	Immediate
	Increase help to entrepreneurs to secure federal SBIR/STTR funds	Short-term
	Secure federal investments to build Arizona's bioscience capacity, including working with the state's Congressional Delegation	Immediate
	Adequately fund Arizona's public higher education system overall; and use bond financing to meet higher education's capital needs for research, laboratory, and education facilities and equipment	Short-term
	Address the need to attract top graduate students to research opportunities in Arizona	Short-term
Strategy Two: Build a critical mass of bioscience firms by increasing the birthrate and reducing the death rate of Arizona's bioscience firms and encouraging the commercialization of research discoveries.	Provide in-depth, comprehensive, entrepreneurial assistance support to start-up and emerging bioscience companies	Immediate
	Support prototype development and proof-of-concept activities from research to commercialization	Short-term
	Invest at earliest stages of firm formation through an Arizona BioSeed Fund	Short-term
	Provide wet-lab space through support of bioscience accelerators/incubators/wet-lab space in and around research parks	Short-term
	Provide a mechanism for Arizona universities to take equity in start-up companies	Immediate
Strategy Three: Offer a business climate and environment that supports, sustains, and encourages the growth of bioscience enterprises, small and large, to start, expand, and remain in Arizona.	Revise state/local economic development programs and the state's tax code to support the growth, expansion, and selective recruitment of bioscience firms	Short-term
	Establish Technology Zones around existing and proposed concentrations of bioscience and other technology industries	Short-term
	Form regional bioscience technology councils as separate organizations or as part of a broader regional technology council	Short-term
	Initiate a statewide image, marketing, and business development effort to market Arizona as a location for bioscience firms	Long-term

Table 11. Summary of Proposed Strategies and Actions for the Arizona Bioscience Roadmap (continued)

Strategy Four: Encourage the state's citizens to become a more informed citizenry in the biosciences and encourage young people to explore and pursue scientific and technical careers.	Create capacity to understand and address health policy issues from review boards and central data banks to ethics and public policy reviews	Long-term
	Address future talent pool by making improvements in science and math in K–12 through graduate education	Long-term
	Encourage talent to remain in the state by expanding co-op and internship programs	Long-term

STRATEGY ONE: BUILD THE STATE'S RESEARCH INFRASTRUCTURE OF OUTSTANDING TALENT AND MODERN FACILITIES AND EQUIPMENT AROUND SELECTIVE TECHNOLOGY PLATFORMS AND CORE COMPETENCIES

An absolute prerequisite for any state to become a world-class bioscience industry center is a world-class higher education and academic health center/clinical practice capacity, with leading-edge researchers and clinicians in the medical, life, and biological sciences. Medical centers, teaching hospitals, interdisciplinary centers on the cutting edge of the "bio"revolution, and model facilities that are well equipped for research and populated by leading researchers are the hallmarks of a respected, nationally recognized bioscience research center. Generally, it is rare to have a cluster of bioscience firms without a corresponding strong set of higher education research institutions nearby.

A recent study by the SBA, the National Commission on Entrepreneurship, and the Kauffman Center for Entrepreneurial Leadership stated the following:

> *University expenditures on research and development promote higher new firm birth rates. The phenomenon is identical to that described by other researchers as "spilover" effects. Just like business firms, research universities form local innovative activity centers, from which both knowledge spillovers and growth in specialized markets generate*

Strengths on which to Build

- State and regional leadership engaged in and supportive of bioscience research

Weaknesses to Overcome

- Losing market share of national bioscience research funding

Opportunities on which to Capitalize

- Arizona is well positioned to grow its bioscience sector in niche market areas, particularly neurological sciences, cancer therapeutics, and bioengineering
- Increased federal funding for bioscience research provides opportunity to capture larger share of bioscience research dollars
- Arizona has existing medical, health, and academic resources on which to build
- A focus on translational research can create a unique niche for Arizona's bioscience base
- State's investment in TGen/IGC could be leveraged to create and enhance partnerships with bioscience companies

Threats to Minimize

- Other states and universities are aggressively pursuing bioscience development

> *higher rates of new firm formation in one or more industries. The glue that holds these clusters together is the effort universities are putting into mechanisms to promote commercialization of the inventions that emerge from their laboratories.*[37]

As discussed previously, Arizona has taken significant and meaningful steps to augment its state support for bioscience research with its health research fund, Proposition 301 funding, and voter approval to dedicate new tobacco tax revenues in part to additional research.

However, even with this infusion of funds, Arizona remains in a "catch-up" position. Other states and regions of the country have allocated more state funding and secured significant federal dollars as the NIH budget has nearly doubled in the last several years. For example, Pennsylvania has committed to invest $2 billion and Michigan plans to invest $1 billion in the biosciences over the next 20 years. As many as 41 states report technology initiatives that support the development of bioscience research and/or bioscience companies.[38]

Examples of Benchmark States' Investments in the Life Sciences

- California is investing $100 million in a bioengineering and biotechnology institute and $500 million in pension funds toward the California Biotechnology Program.
- Georgia has invested more than $300 million over a 10-year period to build core research facilities and to attract Eminent Scholars, the majority of whom are in the life sciences, and has created a $1 billion Georgia Cancer Coalition that is designed to make Georgia a national leader in cancer prevention, treatment, and research.
- Texas appropriated $800 million for seven new or expanded health science research centers.

This combination of increased competition from other states, Arizona's current rankings on and success in securing federal bioscience research dollars, and its current status as a third-tier (or lower) state in the biosciences means that it must find ways to rapidly build its research capacity and, as it does, capture more federal and other leveraged dollars. Sufficient public sector funds for "bricks and mortar" investments, i.e., capital investments, are part of the gap to be filled; but, the gap is broader than that. It also means sufficient public sector operating funds to recruit and attract Eminent Scholars; to offer competitive recruitment packages for emerging young, talented, biosciences faculty; and to build core labs and facilities that are competitive with other academic health and university research centers across the country.

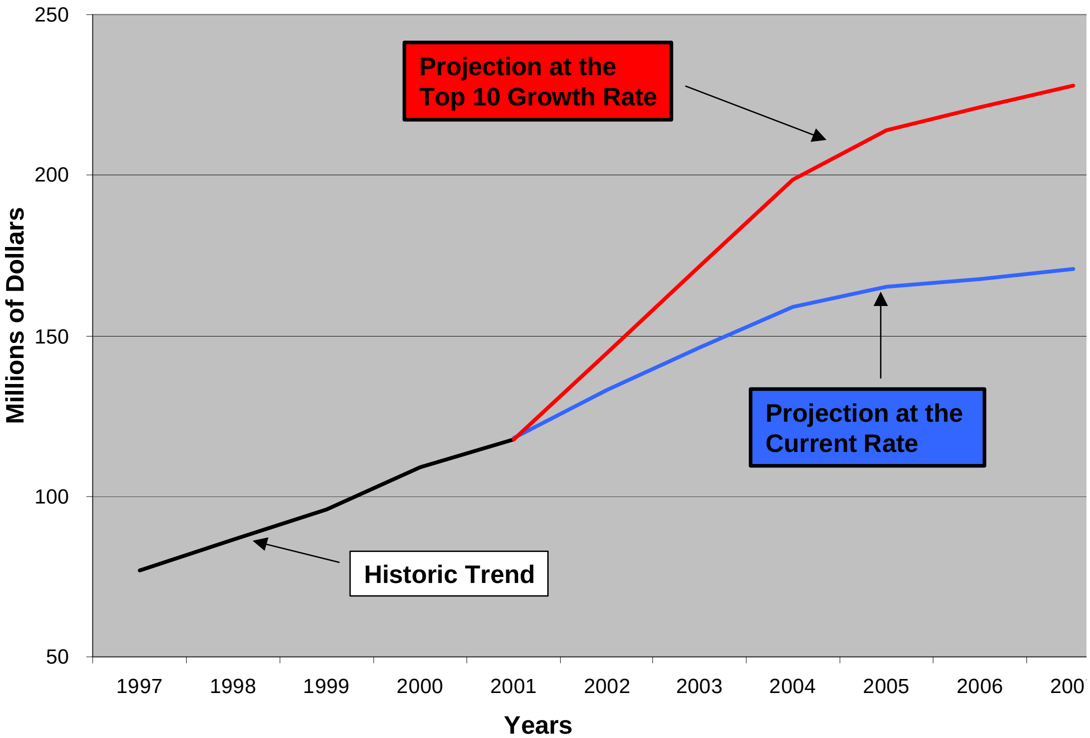
Figure 13 projects Arizona's total NIH funding by the year 2007 if current trends continue. Whereas Arizona might see an increase in NIH funding from the current $118 million to $174 million, an increase of $56 million, this would still place Arizona further behind other leading states. One performance goal suggested for Arizona to establish for itself is achieving, by 2007, a funding growth rate equal to the growth rate for the top 10 states. In short, Arizona's performance goal should be to

> Achieve a rate of funding growth from the NIH equal to that of the top 10 states in NIH funding historically, increasing Arizona's NIH funding totals from $118 million in FY 2001 to $218 million in FY 2007—an increase in NIH funding of $100 million by FY 2007.

---

[37] U.S. Small Business Administration, The National Commission on Entrepreneurship, and the Kauffman Center for Entrepreneurial Leadership. *The Influence of R&D Expenditures on New Firm Formation and Economic Growth*, 2002. p. 24.
[38] See *State Initiatives in Biotechnology 2001*, September 2001.

Figure 13. Projection of Arizona Total NIH Funding (FY 2001 to 2007)



Reaching this NIH performance objective will require corresponding investments by Arizona's research organizations in facilities, core laboratories, research faculty and support staff, and start-up packages to recruit such researchers and scholars. Table 12 lays out the financial implications for every $100 million in NIH funding achieved, based on national figures for costs of construction and recruitment as calculated by Battelle.

Table 12. Requirements to Support $100 Million in NIH Funding

Estimate of One-time Requirements and Costs in Space, Research Groups, and Start-up Packages for Supporting Additional $100 Million in NIH Funding		
Estimate of	**Key Assumptions**	**Requirements**
Space Needs	For every additional $225 of research funding, need additional sq ft of space	444,444 sq ft
Space Costs	Costs $300 per sq ft for construction of basic research labs, not including core labs	$133 million
Core Research Labs	May include structural biology, micro-array facilities, animal facilities, etc.	$25–$50 million
New Research Groups	$900,000 in NIH annual funding per research group	111 research groups including senior PI, assoc. faculty, post-docs, research fellows
Start-up Package Costs	$2 million for start-up packages	$222 million, including equipment, supplies, etc.
Total One-Time Costs		**$380–$405 million**

Note: In addition, there will be ongoing operating costs for facility and for a portion of faculty salaries.

Public-private partnerships will need to be formed to address these facility, faculty, and instrument needs if Arizona is to position itself in the biosciences. TGen and IGC represent a first installment in addressing the need to secure both additional federal research funds and funds for facilities, equipment, and other research infrastructure. These two organizations will increase the flow of federal NIH funds to Arizona both by recruiting researchers, who will bring funding with them, and by improving the capabilities of Arizona's existing research organizations to compete more successfully for NIH awards. The $90 million contributed by state, private sector, philanthropic, and university sources to attract TGen/IGC to Arizona will help Arizona partially meet the earlier stated goal of an additional $100 million annually in NIH funding (perhaps by 25 percent). It will also help the state to partially address the additional $380–$450 million that will be needed around technology platforms to attract these federal funds.

As addressed below under "Tactics," this strategy and achieving the performance objective of increased NIH funding equivalent to the historical growth rate of the top 10 states can be achieved only if Arizona

- Focuses on its core research capabilities and technology platforms—neurological sciences, cancer therapeutics, and bioengineering—during the next five years.
- Works through multi-institutional collaboration taking advantage of capabilities among research universities, hospitals and medical centers, and other research organizations to "jump–start" Arizona, which is currently in a "catch-up" position.
- Addresses the need to further improve its research stature in the short term and both its research stature and technology commercialization capabilities over the mid to long term.

Tactics

This section outlines the key tactics that will help position Arizona to accomplish this strategy and describes the suggested actions to be implemented in support of this strategy:

- **Focus Arizona's efforts to further build its bioscience research capacity by targeting on key core competency/technology platform areas** (outlined elsewhere in this document)
- **Focus state investments on key research infrastructure investment,** including facilities at its research universities that can attract and house faculty, offer specialized facilities around core competency areas not otherwise commonly available in competitor states/regions, and recruitment packages to attract current and emerging stars
- **Encourage multi-university collaboration** through consortia, joint ventures, and alliances similar to those being organized in support of IGC and TGen. Such collaborations will be required in other technology platform areas in order to maximize expertise, resources, and complementary competencies across institutions
- **Build and expand the basic science and research base** in ways that build the foundations for technology platforms that can lead to applications and commercialization in such areas as cell and development biology, functional human genetics, proteomics, and computational biology.

- **Broaden the state's bioscience clinical research infrastructure,** which currently has limited application strengths in specific diseases such as cancer and neurological disorders, but with potential in such areas as infectious diseases, asthma, and diabetes.
- **Attract both existing as well as emerging stars to the state** through a combination of public, private, and philanthropic support to fund competitive recruitment packages that help build platforms and core competencies in which Arizona will excel.

Actions for Strategy One

It is proposed that Arizona pursue a broad set of reinforcing actions to build its capacities in the biosciences that address simultaneously the needs for adequate facilities, the recruitment of researchers, and acquisition of equipment and specialized laboratories, and in other ways further build the state's research capacity in its higher education, academic health, hospitals, and other institutions. The following actions are included under Strategy One:

Action One: Establish a statewide fund (the Arizona Bioscience Research Enhancement Fund) to enhance bioscience research.

Action Two: Stimulate research collaboration among universities, hospitals, and other research organizations by creating consortia, centers, and institutes in bioscience technology platform areas and related engineering/information technology areas that are essential to further position Arizona in the biosciences.

Action Three: Establish a Bioscience Matching Challenge Program to connect industry and researchers and to encourage university-industry partnerships.

Action Four: Increase help to entrepreneurs to secure federal Small Business Innovation Research (SBIR) Program and Small Business Technology Transfer (STTR) Program funds.

Action Five: Secure federal investments to build Arizona's bioscience capacity, including working with the state's Congressional Delegation.

Action Six: Adequately fund Arizona's public higher education system overall; and use bond financing to meet higher education's capital needs for research, laboratory, and education facilities and equipment.

Action Seven: Address the need to attract top graduate students to research opportunities in Arizona

Action One: Establish a statewide fund (the Arizona Bioscience Research Enhancement Fund) to enhance bioscience research.

Rationale: For Arizona to "catch up" with other states in the biosciences, it will need to address a basic prerequisite for biosciences development: a well-developed research infrastructure. This will require a flexible funding source that Arizona's research universities and associated other research organizations, such as St. Joseph's/Barrow Neurological Institute, can tap to attract talent (endowed chairs), construct and equip facilities, and provide match for federal and industry funds. This approach has been successfully implemented by others. For example:

- Since 1992, the State of Georgia has invested more than $300 million in GRA-directed programs. These funds have been used to provide endowments and state-of-the-art laboratories for Eminent Scholars, to create core research facilities that can be used by both academic and industrial researchers, and to support commercialization programs. These investments have resulted in increased awards for bioscience R&D to Georgia's universities. Georgia currently ranks 11th in NIH awards.

- The Oregon Health Science University has increased its NIH funds from $85 million in FY 1995 to over $200 million today, and recently received an additional $200 million from the state's portion of the tobacco settlement proceeds, to be used for facilities, faculty, and recruitment packages.
- The Pittsburgh Life Sciences Greenhouse has been created to build on the strengths of the University of Pittsburgh/Carnegie-Mellon University and has raised $120 million in foundation, state, and university support for its first five-year Phase I effort to position the city and region in the life sciences.

Other similar programs in the benchmark set are summarized in Table 13.

Table 13. Summary of Bioscience Funding Programs in the Benchmark Set

State/Region	Entity/Programs	Notes on Scale
Georgia	Georgia Research Alliance • Eminent Scholars • Laboratories • Technology development centers	Total of $20–$30 million annually from the state, matched on project basis by industry or federal government
	Cancer Initiative	$400 million from tobacco settlement, leveraged to $1 billion
North Carolina	North Carolina Biotechnology Center ▪ Academic Research Initiation Grants (<$55K) ▪ Institutional Development Grants ($650K if not coupled to a recruitment; no maximum if coupled) ▪ Interdisciplinary Research Grants ($250K/project)	Approximately $10 million/year for all programs, including these and several others
Oklahoma	Oklahoma Institute of Technology Trust Fund	Endowed by state with $1 million, charted to raise a total of $100 million from private sources
	Oklahoma Center for Advancement of Science and Technology Health Research Program (<$45K over three years)	
San Diego	Cal Institute for Telecommunications and Information Technology (nonbiosciences)	$100 million in state capital funding for this Institute alone, one of four "organized research units" that cross campuses and are expected to leverage industry donations and sponsorship

Table 13. Summary of Bioscience Funding Programs in the Benchmark Set (continued)

State/Region	Entity/Programs	Notes on Scale
San Diego	San Diego Regional Technology Alliance/California Technology Investment Program (<$250K, matching federal award)	>$2 million/year including operating expenses
Texas	Texas Higher Education Coordinating Board ▪ Advanced Research Program (ARP) competitive grants ▪ Advanced Technology Program (ATP) competitive grants	ARP funded at $20 million annually; ATP at $40 million, with a setaside for technology transfer
	Texas Excellence Fund and University Research Fund, allocations based on universities' leverage of external research funding	Financed from $30–$50 million in earnings on state's $2 billion higher-education permanent endowment

Programmatic Description: An Arizona Bioscience Research Enhancement Fund will provide flexible dollars to enable the state's research organizations (research universities, health centers, others) to receive funds needed to build facilities, equip labs, attract talent, and build the research teams necessary not only to build Arizona's stature further in its technology platforms, but to attract additional personnel and become more competitive in seeking and securing federal, industry, and other financial support for enhancing the research enterprise. Funding must be flexible, but focused, and must be provided over a five- to ten-year period, such as in Georgia and elsewhere.

The Arizona Bioscience Research Enhancement Fund would strategically invest its funds in existing and emerging technology platforms around which Arizona is to build its future in the biosciences. It would do this in several ways:

- Make funding awards for facilities, equipment, and new faculty lines
- Offer funding support for recruitment packages for stars/emerging stars
- Link its funding decisions with those of other groups and organizations, including research universities, hospitals and medical centers, industry, and philanthropic organizations.

Resources Required: TGen/IGC represents the first installment in an overall effort to seek and secure an additional $100 million annually in NIH awards by 2007. To reach this level, $380 to $450 million in other investments in facilities, recruitment packages, labs, etc., will be necessary. Part of this facility need is being addressed by projects that are approved, in the process of being approved, or being proposed to the Arizona Board of Regents. The State of Arizona will need to find additional ways to increase the scale, level, and speed at which research facilities are built and the funding associated with both construction and ongoing operation.

Subject to further review, a conservative estimate would be that at least $42 million a year in additional operating funds for the next eight years, or a total of $336 million will be needed around investments in the technology platforms. Sources to address these operating fund needs include Proposition 301, cigarette tax increase, and additional state appropriations. Some portion of this Board of Regents capital projects list also addresses investments in the near-term technology platforms, but not all. Further review will be necessary to determine additional dollars needed for one-time capital projects. These estimates could be further refined as Arizona's research universities, other research institutions, and the Flinn Foundation move forward with developing strategic business frameworks for each technology platform.

Both Proposition 301 funds and funds from the cigarette tax increase enacted in November 2002 can help address this resource need, further supplemented by private fund raising such as that being undertaken by Barrow. See Action Six regarding state funding support of capital projects as an important source of funds to move this action forward.

Time Frame: Immediate, but funded over the mid and long term. Because building a sufficient research scale is a prerequisite to Arizona's bioscience competitiveness, funding needs to be identified and supported immediately.

Lead Organization: Several possible vehicles or mechanisms could be used to direct and channel these primarily public funds:

- The Arizona Disease Control Research Commission, which administers the state's Health Research Fund, could serve as a possible manager/implementation arm for this fund.
- The Arizona Board of Regents could manage the fund, as it now manages the Proposition 301 funds.
- A new entity, similar to the Georgia Research Alliance, could be created to manage the fund, among other responsibilities.

Given other fundamental proposed responsibilities, the Arizona Bioscience Research Alliance, which is described in the "Implementation" section of this report, is suggested as the appropriate solution. Its role is to assure focus by all stakeholders and to monitor developments, identify gaps, and address needs and issues as they arise from time to time in this Roadmap's implementation, including use of the Bioscience Research Enhancement Fund.

Obviously, this choice will be affected by preferences of both the Governor and Legislature; but, formation of the alliance and its involvement in the design and development of the fund could ensure a close partnership with the state government, ensuring accountability for public funds, while maximizing the private sector and higher education partnership with the state.

Action Two: Stimulate research collaboration among universities, hospitals, and other research organizations by creating consortia, centers, and institutes in bioscience technology platform areas and related engineering/information technology areas that are essential to further position Arizona in the biosciences.

Rationale: Each of Arizona's research universities has been addressing the need to encourage interdisciplinary research in the biosciences. Because of the importance of cross-disciplinary work in emerging fields of disease treatment and care that have brought together the tools of information technology applied to the breakthroughs of genomics and proteomics, universities throughout the world are recognizing the need for interdisciplinary endeavors to build strengths in the biosciences. While Arizona's public universities have, in varying degrees, pursued such efforts, they must continue and expand these efforts. Collaboration across institutions, which is at its early stage, both among the research universities and with other important research, medical treatment, and educational providers, including hospitals, medical centers, and education institutions, will become increasingly important.

Given Arizona's current position in the biosciences, collaboration across and within institutions in key competency areas is a clear way for the state to establish excellence more quickly than an approach treating all disciplines and research areas equally. This "jump start" effort will occur more rapidly, the state and its partners will reach national and international stature more quickly, and the ability to leverage outside dollars and build a critical mass of Arizona-based firms is more likely in a shorter time period as well.

Programmatic Description: This action will use the Bioscience Research Enhancement Fund to put into place the appropriate incentives to encourage collaboration among and between Arizona institutions in the biosciences, including formation of centers and consortia in key technology platforms.

The primary action is to encourage institutions to move forward in complementary fashion to develop and create the interdisciplinary centers, institutes, or consortia—as the case may be—to build Arizona's strengths in the technology platform areas described previously. Partly, this is opportunistic; partly, an effort at strategic management.

Rather than all organizations moving independently ahead to position themselves in the biosciences, which is more often the case, Arizona and its leaders in private and public research universities and organizations must work in a complementary fashion to establish the necessary research infrastructure, including centers, institutes, or consortia, that enable partners to work together with focus, building depth and capabilities by joining forces.

TGen and IGC represent concrete examples of such an effort coming forward through a private-public partnership. Similar efforts must be encouraged in other technology platforms on which Arizona can build its bioscience efforts. The Arizona Research Consortium (ARC), which is seeking to build the state's clinical research and trials capabilities, is another example of a collaborative effort already underway. Other examples include the Mental Health Institute, which brings together researchers in the neurological sciences, and the BioDesign Institute, which promotes collaboration in bioengineering. Each is an example of the kinds of mechanisms, organizations, and partnerships that Arizona must create in the future. In encouraging the formation of such centers or institutes, their funders should focus efforts on pre-clinical trial, translational research, guided by multi-institutional collaboration.

Incentives to encourage these efforts include the following:

- Encouraging state administrators of Proposition 301 and health research funds both to focus state funds in platform areas and to permit/require some portion of funds to encourage multi-institutional and interdisciplinary efforts.
- Providing discretionary collaboration funds to each research university president to be used for collaboration within identified platforms through philanthropic or private funding sources.
- Using the Arizona Bioscience Research Enhancement Fund (see Action One) in ways to encourage and reward collaborative efforts.

Resources Required: Research centers, institutes, and consortia can range in funding size from several hundred thousand to several hundred million dollars. This discussion includes centers/ institutes/consortia that represent TGen/IGC on the higher end of the funding continuum to ARC on the lower end of funding support, funded at several hundred thousand dollars per year. By implementing this action in a complementary fashion to Action One, the same funding sources would be used. Additional funding support for university presidents to encourage collaboration would range in the $3 to $5 million per year per research university to have significant impact. In addition, one-time costs of $400 million for capital projects around the platforms can be expected.

Time Frame: Immediate. Efforts should focus on moving forward TGen and IGC, along with ARC. In the mid-term, a third center will be needed in the bioengineering technology platform area and/or in the cancer therapeutics/neurological sciences areas. Total funding from all sources for a center with scale and significant impact should be at least $50 to $60 million a year, with a good portion of this base represented by federal funding awards.

Lead Organization: Similar options to those of Action One are possible. In this instance, the organization responsible for the Arizona Bioscience Research Enhancement Fund should be applying the collaboration principles to its efforts; similarly, the Board of Regents should be offering incentives. Foundations may wish to consider giving research university presidents flexible dollars to be used as incentives for multi-institutional collaboration in the biosciences.

Action Three: Establish a Bioscience Matching Challenge Program to connect industry and researchers and to encourage university-industry partnerships.

Rationale: To build a strong, nationally competitive research enterprise, research universities and organizations increasingly are partnering with local and national firms. While Arizona currently does not have a critical mass of bioscience firms, it does have a 4,000-worker medical device industry and a number of other—generally smaller—research, pharmaceutical, testing, diagnostic, and other firms developing products and processes. Finding ways to link the needs of firms and the expertise of research and medical faculty and to undertake collaborative research, translational research and applications can benefit faculty interested in seeing their ideas developed and firms needing new ideas and concepts to build their companies. For the state and its citizens, this represents a way for its higher education investment to be accessible and beneficial to its industry.

States throughout the country have developed a number of programs that relate to this effort, ranging from Kentucky's research and development voucher program and Pennsylvania's Ben Franklin Partnership Program to the Utah Centers of Excellence Program. California's Regional Technology Alliance program operates similarly and is tied to attracting federal funds into the state.

The Utah program is somewhat misnamed; it is really a project grant program, not a centers program. Nevertheless, it represents an example of a challenge grant program intended not only to build the capacity to attract federal funding, but to create enduring academic/industrial partnerships that lead to ongoing support and commercialization of intellectual property within the state. Budgeted at approximately $2 million a year, the Centers program supports nearly 15 projects at any one time, with allocations up to a maximum of $200,000 per project.

The program supports faculty at Utah universities, helping them to advance the research program in a way that attracts interested industrial partners from within the state. Center grants can pay for basic or applied research and may be used to retain consultants who can write "business plans" for the technologies under development. State funding must be matched by industrial partners.

Since 1986, a total of nearly 80 projects were funded at a cumulative investment of $832 million, matched 10:1 by funds from industrial partners. The Centers program is aimed at producing commercialization within a three- to five-year window and is credited with the creation of 134 new companies and 184 license agreements.

Other similar programs in the benchmark set are summarized in Table 14.

Table 14. Summary of Programs Promoting University-Industry Partnerships in the Benchmark States

State/Region	Entity/Program	Notes on Size/Scale
Georgia	Georgia Research Alliance Technology Development Partnership Program ($50K–$80K per project, with 1:1 match required)	Applied research and development
North Carolina	North Carolina Biotechnology Center/NC State Kenan Institute Collaborative Funding Assistance Grants (up to $45K/year per project for three years, 1:3 match required)	
Oklahoma	Oklahoma Center for Advancement of Science and Technology Applied Research Support (<$300K per project, over three years, with 1:1 match required)	
Texas	Texas Higher Education Coordinating Board Technology Development and Transfer Setaside, 1:1 match required	$8 million within $40 million ATP program
Utah	Utah Department of Commerce and Economic Development Centers of Excellence Program ($200K per project for three to five years)	$2 million/year

Programmatic Description: To assist Arizona's existing firms and to encourage the formation of new enterprises, a Bioscience Matching Challenge Program is proposed. The primary purpose for such a program is to establish and build relationships between academic and medical personnel and associated firms within Arizona. Funds would be awarded on a competitive basis, with a 3:1 industry match required, including at least a 1:1 cash match. Funding would total at least $100,000–$250,000 per year, with maximum awards limited to three years. This funding level addresses problems in other states where the size of the awards are too small to encourage scale and impact. University intellectual property policies would apply; however, the industry participant would have a "first right of refusal" for an exclusive licensing option for a funded project.

Resources Required: To encourage the building of relationships, this program could be funded initially at $750,000, with plans to expend $6 million a year by year ten if successful. The

Health Research Fund or some portion of the state's 301 funds could be used to establish this program.

Time Frame: Immediate to short-term

Lead Organization: Similar options are suggested as delineated in Actions One and Two: the Arizona Disease Control Research Commission, the Arizona Board of Regents; or the Arizona Bioscience Research Alliance. Because of the alliance's focus on facilitating industry/higher education partnerships, Battelle suggests the alliance as the preferred administrator of this program.

Action Four: Increase help to entrepreneurs to secure federal SBIR/STTR Program funds.

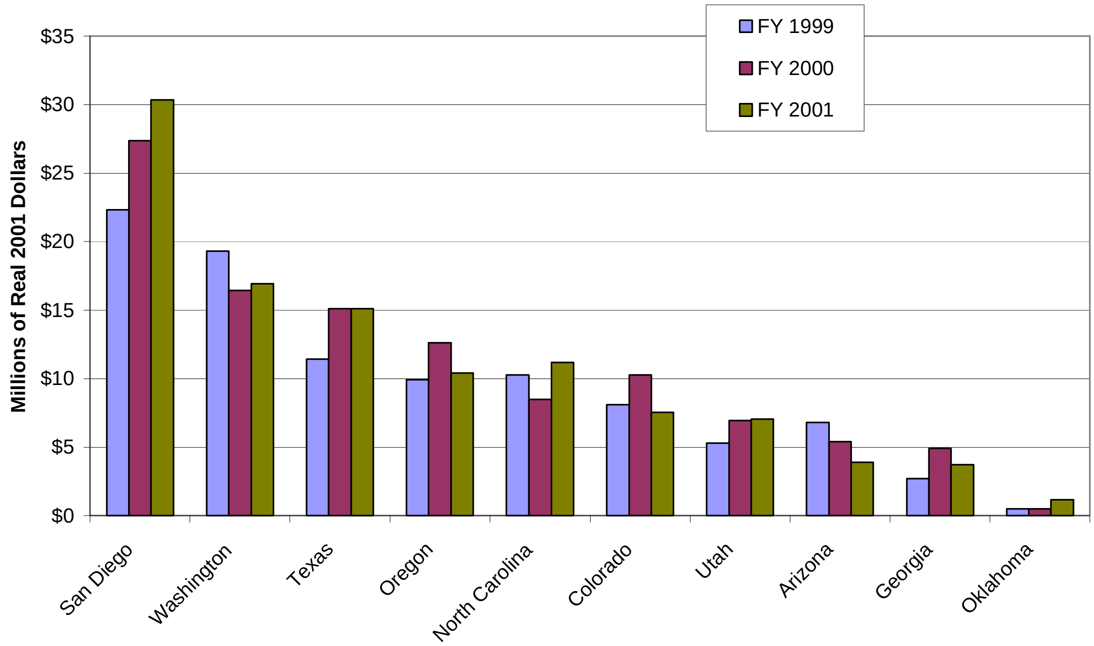
Rationale: Another important source of risk capital is the federal SBIR/ STTR program. This program requires all federal agencies with annual extramural research and development budgets of more than $100 million to set aside 2.5 percent of those monies to competitively fund innovative research conducted by small businesses. Since it was initiated in 1982, the SBIR program has grown to become the single largest source of competitive, early-stage, research and technology development funding in the country for small businesses. Today, the SBIR program awards more than $1 billion annually. One way to gauge the level of bioscience research occurring in a state is to examine the number of NIH SBIR awards going to a particular region or state.

Arizona ranks eighth among the benchmarks in terms of the number of NIH SBIR and STTR grants awarded. Figure 14 displays the awards made by NIH through SBIR and STTR programs for FY 1999, FY 2000, and FY 2001. San Diego and Washington lead the set of benchmarks in securing SBIR and STTR awards funded by NIH, with between $16 and $30 million per year. Arizona is far behind, capturing less than $7 million each year. In addition, the award level has decreased each of the past three years, with the FY 2001 award level below $4 million. During the same time period, Arizona received no SBIR awards sponsored by the Department of Agriculture.

When the number of SBIR and STTR awards are examined for all agencies over the last five years, Arizona fares better, ranking fourth among the benchmarks (see Figure 15).

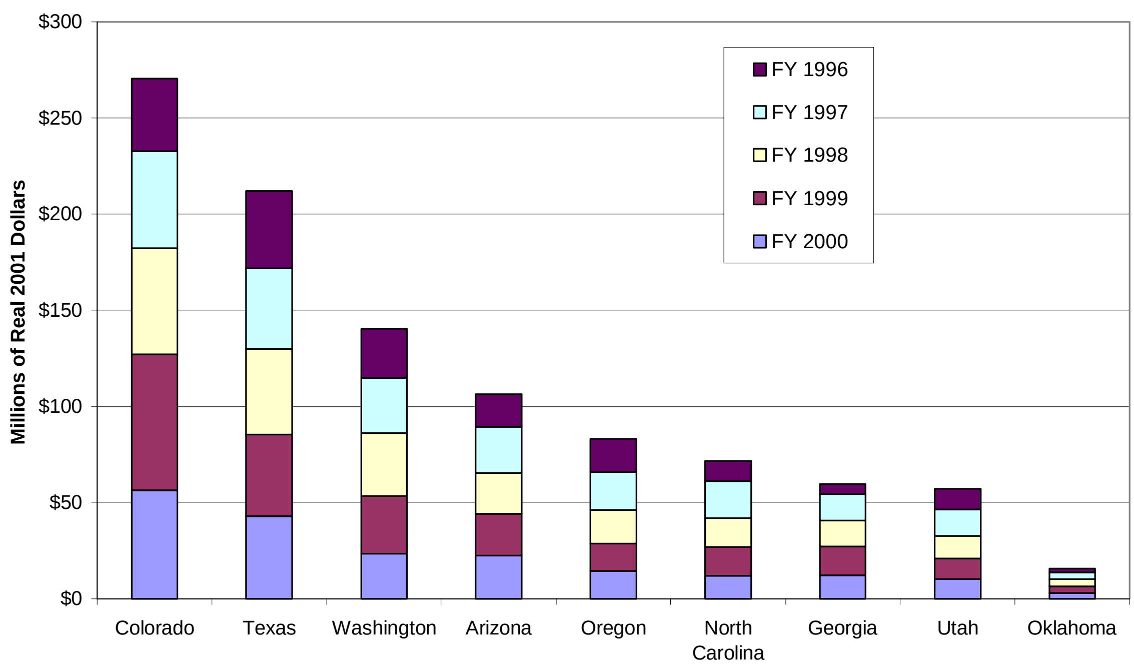
Experience has shown that investments in programs and activities can help entrepreneurs better compete for funding from the federal SBIR program (and its counterpart STTR program where Phase I is done in the university and Phase II in the firm) Program and can increase a state's success rate. Because Phase II awards from NIH are now approaching several million dollars, SBIR represents a good opportunity to both create firms and build partnerships with higher education to undertake the SBIR work (no more than 49 percent of an award can go to a university partner).

Figure 14. National Institutes of Health—SBIR and STTR Awards



Source: National Institutes of Health.

Figure 15. SBIR and STTR Awards, All Agencies, FY 1996–2000



Source: Small Business Administration.

Programmatic Description: In October 2002, Arizona was awarded a Small Business Administration (SBA) Federal and State Technology (FAST) Partnership Program grant to promote small business development. The $200,000 program, which was funded by a $100,000 grant from the SBA and matched equally by the Arizona Department of Commerce (ADOC), will allow the ADOC Office of Innovation, Technology and Entrepreneurship and a coalition of Arizona academic and technology organizations to provide assistance to small technology firms. As part of this new program, Arizona should initiate a Bioscience SBIR support program, providing seed funding support to an organization or organizations that will assist entrepreneurs interested in seeking federal SBIR bioscience support . The SBIR assistance program would provide the following services:

- Literature searches and scientific reviews
- Identification of expert consultants for inclusion in the management team
- Proposal preparation
- Identification of opportunities with federal funding agencies
- Development of follow-on commercialization plans and identification of third party sources of financial support.

If Arizona would receive just a few Phase I SBIR awards and convert half to Phase II awards, this program would leverage significant federal funds, result in the creation of additional research jobs in the state, and help grow a critical mass of cutting edge bioscience firms.

Resources Required: $400,000 to $600,000 a year to support one staff person and consultants needed to provide advice and counsel to bioscience entrepreneurs. The $200,000 award from the SBA FAST SBIR Program can be used to move this initiative forward.

Time Frame: Short-term

Lead Organization: Arizona Bioscience Research Alliance or regional Bioscience High Technology Councils

Action Five: Secure federal investments to build Arizona's bioscience capacity, including working with the State's Congressional Delegation.

Rationale: More states, through their public and private representatives, have been working more closely with their Congressional Delegations to ensure federal investments that help create the research and research infrastructure anchors that help build bioscience economies. As noted in the "Benchmarking Analysis" section, one key lesson for states and regions building a bioscience economy is the importance of federal funds for federally designated centers and institutes, whether the funding comes in the form of operating or capital funds. Almost every major mature bioscience region or state in the United States has one or more federal "anchors" that have contributed to building its bioscience base, e.g., the National Institute of Environmental Health Sciences (NIEHS) in Research Triangle Park, Lincoln and Draper Labs in Boston, and NIH in Maryland. Discretionary federal funding unfettered by federal mission also plays a role in enabling exploratory research to be undertaken that may lead, many years later, to applications in the health and biomedical arenas.

Increasingly, states, ranging from Missouri and Pennsylvania to Ohio and Connecticut, are seeing the benefits from such federal investments. Missouri’s efforts in working with its Congressional Delegation has brought in $25 million a year for the past several years. This funding is helping to build the University of Missouri system’s research infrastructure, which has been adversely affected by a shortage of state capital funds. Research infrastructure funding is generally not available from federal grant programs, necessitating efforts to identify and secure discretionary federal funding support.

Programmatic Description: It is suggested that Arizona’s research universities, state government, and industry leadership identify annually those parts of this bioscience roadmap that could benefit from federal funding and investment. This multi-year strategy provides the basis for identifying an annual Arizona Congressional Delegation agenda to secure discretionary federal infrastructure and research funding support.

Resources Required: No direct funding is needed; rather, this function needs to be lodged in some organization and actively undertaken and updated.

Time Frame: Immediate

Lead Organization: The most likely lead organization is the proposed Arizona Bioscience Research Alliance.

Action Six: Adequately fund Arizona’s public higher education system overall; and use bond financing to meet higher education’s capital needs for research, laboratory, and education facilities and equipment.

Rationale: Since the early 1980s, Arizona has generally financed its higher education facilities on a pay-as-you-go basis. The State of Arizona will need to find additional ways to increase the scale, level, and speed at which research facilities are built and the funding associated with both construction and ongoing operation. Even so, higher education institutions are forced to raise private, alumni, and other funds for research buildings and facilities to move forward. The Arizona Legislature has recently given higher education increased ability to develop and manage a more aggressive revenue-bond financing effort, subject to project approval by the Legislature. But, because of restrictions on state revenues and dedication of various revenue streams with expenditure requirements, funding higher education needs and requirements from revenue bond sources only is likely to become more difficult. Unlike many other states that use their general obligation bonding authority directly to finance classrooms, research buildings, and, in some instances, medical facilities, Arizona has a much more convoluted approach. Because of the importance of higher education to the state’s future economic development, recent shortages in the state’s general operating funds, and the uncertain nature of the economy over the short term, those interested in Arizona’s bioscience development need to be concerned about the ability of higher education to continue to fund the research infrastructure in Arizona. In recent years, Arizona has underinvested in its higher education infrastructure. If this continues, the bioscience recommendations in this report would be placed on top of a severely deprived, nonfunctioning, higher education core base.

Programmatic Description: It is proposed that the Governor and Legislature, working with higher education and industry leaders, develop a clear path and approach, through a multi-research university authority or other means, to increase the scale and level of direct or indirect state government funding for research and related higher education facilities, using the state's bond financing capabilities to ensure that Arizona's higher education institutions have the research infrastructure to be competitive in the biosciences.

Resources Required: To address the recommendation, only staff resources would be required. Should higher education be given access to general obligation bond financing, the state will incur interest costs associated with the debt issued.

Time Frame: Short-term

Lead Organization: Governor of Arizona and Arizona Legislature, with advocacy of proponents of higher education access to general obligation bond authority.

Action Seven: Address the need to attract top graduate students to research opportunities in Arizona.

Rationale: As Arizona builds its research base, it also will need to focus increasingly on translational research, requiring that students and graduates be proficient in both research and clinical practice. A concerted effort to recruit and attract the best graduate talent would help Arizona further build its research base. A discriminating factor in state and regional competitiveness in the biosciences is the talent pool. Attracting the "best and brightest" nationally to undertake their graduate education in Arizona would further build Arizona's competitive advantage in the biosciences.

Programmatic Description: Encourage and attract the best graduate students to pursue their advanced education in Arizona through a Graduate Fellows Program in the biosciences. Such a program would further build the state's bioscience talent pool.

Resources Required: $1.8 million per year.

Time Frame: Short-term

Lead Organization: The Arizona Board of Regents, in cooperation with the Medical College of UA and other hospitals and medical centers.

STRATEGY TWO: BUILD A CRITICAL MASS OF BIOSCIENCE FIRMS BY INCREASING THE BIRTHRATE AND REDUCING THE DEATH RATE OF ARIZONA'S BIOSCIENCE FIRMS AND ENCOURAGING THE COMMERCIALIZATION OF RESEARCH DISCOVERIES

In addition to building Arizona's research strengths, the state must also focus on converting research into marketable products and/or services. To do so requires states to focus on initiatives that foster entrepreneurial development and catalyzes commercialization activities.

Arizona already ranks extremely high in metrics that attempt to rank its overall entrepreneurial culture. In the Progressive Policy Institute's *The 2002 State New Economy Index*, Arizona ranked fifth in the nation in economic dynamism, which is defined as a state's ability to foster the creation of new firms, support firms that innovate, and cultivate a culture that is epitomized by fast-growing, entrepreneurial companies. The state's fifth place ranking fell behind only two benchmarks, Washington and Colorado (although California did rank second.)

While Arizona has ranked high in many studies of entrepreneurship, and the economic analysis earlier in this report showed considerable growth in most bioscience industry segments regarding the number of establishments, Arizona does not yet have a "critical mass" of bioscience firms. Therefore, emphasis must be placed on developing emerging firms within the bioscience sector. Bioscience start-ups have unique needs and requirements that must be addressed to ensure their successful maturation.

Economic payoffs from investing in the commercialization of the biosciences can be significant. Across high-technology industries, studies have shown that academic research contributed most to the drug and medical product industries. One study found that 31 percent of new products and 11 percent of new processes in the biomedical field could not have developed without substantial delay had there not been academic research.[39] But, research by itself does not generate economic development results. Much of Silicon Valley's success, for example, is attributable not only to the world class research conducted at Stanford University, but also to Stanford's policy of encouraging its faculty and students to commercialize research they have developed.

Bioscience firms want to be located close to academic health centers, university research centers, and faculty and post-docs for quick access to sources of knowledge, know-how, and problem-solving skills; to unique equipment, instruments, and facilities; to sources of talent to attract and hire to remain competitive; and to intellectual property to "bundle" related technologies with theirs. For all these reasons, linkages must be established between industry, universities, and academic health centers. Technology commercialization involves bridging the gap between innovations and discoveries and the commercial development of those discoveries by bioscience businesses. These three key components of technology commercialization must be addressed in any state:

Strengths on which to Build

- Strong history of entrepreneurship in traditional industries
- Small but rapidly expanding number of bioscience companies

Weaknesses to Overcome

- No strong tradition of commercializing technology or encouraging entrepreneurship by universities
- Region lacks necessary ingredients for a bioscience entrepreneurial culture
- Insufficient bioscience–focused venture capital and angel investors
- Insufficient wet-lab space

Opportunities on which to Capitalize

- Growing commitment to technology commercialization at the state's research universities

Threats to Minimize

- Lack of sufficient capital at the right stage may deter entrepreneurial start-ups from starting or growing in the state
- Lack of support for emerging bioscience companies may result in their decision to move out of state

- The technology transfer function—including policies, structure, incentives, and approach. Cutting-edge programs aggressively pursue patenting, licensing, and faculty disclosures. They encourage spin-offs where justified, as well as licensing with fee and royalty

[39] Edwin Mansfield, "Academic Research and Industrial Innovation," *Research Policy*, 1998, 26:773-776.

payments. In leading universities, such functions are also being expanded to include technology commercialization.

- Assessing the market and commercial viability of intellectual property, finding funding support to assess the value of research discoveries, and developing a commercialization plan and funding proof-of-concept/reduction-to-practice development. Purdue University and others are putting in place funding mechanisms to do this.
- Firm start-up support, whereby the technology transfer and commercialization functions are broadened to actually finding and accessing seed capital, management talent, and marketing help. Some universities have created third-party intermediaries to play this role, from Mayo and Baylor to Carnegie Mellon and Ohio State.

To become a leading-edge bioscience state, Arizona must create a stronger innovation climate in which entrepreneurs blossom and mature, whether directly out of university and academic health center research or from their efforts. Faculty incentives to encourage moving their research to application need to be further strengthened. Active university and state policy leadership that emphasizes that faculty roles are not only education, research, and public service, but also economic development contribution, may be required. In addition, ways must be found to overcome restrictions on the public universities' ability to take equity in spin-offs.

Furthermore, bioscience entrepreneurs must have access to the financial capital needed to start their firms and to the wet-lab space in which to grow their firms. Finally, in-depth comprehensive entrepreneurial support services that can help firms to survive and grow are crucial.

Tactics

The following key tactics will help position Arizona to accomplish this strategy:

- Addressing the need for networking and providing access to capital, managerial support, talented entrepreneurs, and knowledgeable service providers.
- Providing in-depth support to bioscience entrepreneurs. Referral mechanisms are not sufficient; someone needs to have responsibility for focused, in-depth support to bioscience entrepreneurs.
- Focusing on technology commercialization and business formation in addition to traditional technology transfer.
- Addressing technology infrastructure needs, including space for start-ups and their expansion and capital financing at all stages.

Actions for Strategy Two

It is proposed that Arizona pursue a broad set of reinforcing actions to build a stronger entrepreneurial base focused on the biosciences, which will result in an increase in the number of start-ups and subsequent retention and growth of these firms. An entrepreneurial base can be developed in the state by addressing the technology infrastructure needs of bioscience firms and individuals, including mentoring support, prototype development assistance, pre-seed and seed financing, and wet-lab space. In addition, clearly identifying policies and programs that

Arizona's research universities can implement to encourage the commercialization of its research is critical.

The following actions are included under Strategy Two:

Action One: Provide in-depth, comprehensive, entrepreneurial assistance support to start-up and emerging bioscience companies.

Action Two: Support prototype development and proof-of-concept activities from research to commercialization.

Action Three: Invest at earliest stages of firm formation through an Arizona BioSeed Fund.

Action Four: Provide wet-lab space through support of bioscience accelerators/ incubators/wet-lab space in and around research parks.

Action Five: Provide a mechanism for Arizona universities to take equity in start-up companies.

Action One: Provide in-depth, comprehensive, entrepreneurial assistance support to start-up and emerging bioscience companies.

Rationale: Building Arizona's research base is a prerequisite to creating a set of industries in the biosciences. But, ways also must be found to commercialize that research and develop an entrepreneurial culture. An entrepreneurial culture is difficult to describe; however, it is an important contributor to building a bioscience-based economy. In places with a strong entrepreneurial climate, starting a company is seen as a routine matter, rather than as an unusual occurrence; and a company failure is viewed as a possible outcome of doing business, not as a cause of embarrassment. An entrepreneurial culture, best recognized by its sustained critical mass of emerging companies, includes access to business support services, value-added networking, and capital, including pre-seed funds and commercialization funds. It is also related to university technology transfer and commercialization activities and a seasoned workforce of individuals with entrepreneurial talent.

Other similar programs in the benchmark set are summarized in Table 15.

Oklahoma Technology Commercialization Center

Among the benchmark set, a well-known program that promotes entrepreneurial development is the Oklahoma Technology Commercialization Center (OTCC). OTCC plays an important, and generally neglected, role in Oklahoma by positioning Oklahoma entrepreneurs to grow viable businesses. One important way is by helping start-ups focus their business plans and strategies through hands-on educational and training support and detailed consulting. OTCC also helps entrepreneurs secure angel financing and other early-stage funding (including a state seed fund program that it operates). OTCC has helped organize 44 angel investor groups across Oklahoma, involving 300 investors with a net worth of $2 billion. Moreover, OTCC has established a certified Service Provider Program, which identifies proven, quality service providers representing intellectual property law, corporate law, business consultants, marketing, engineering, science, and financial consulting, who are interested in providing assistance and support to technology entrepreneurs. The most important contribution of OTCC is its activities in helping to stimulate investment deal flow, as well as improving the quality of deal flow to private investors. In its first two years of operation, OTCC has served 467 clients, of which 268 have received detailed project assistance and 74 have been presented before angel investor and other financing sources. Nearly $15 million in hard-to-find pre-seed and seed capital dollars have been raised, leveraging more than four times the amount of state investment in OTCC operations.

Table 15. Summary of Entrepreneurial Assistance Programs in the Benchmark States

State/Region	Program	Notes
North Carolina	Council for Entrepreneurial Development	Independent nonprofit based at Research Triangle Park with 5,000 members representing 1,100 companies
Oklahoma	Oklahoma Technology Commercialization Corp.	Stages entrepreneurs through a mentoring system before they can have access to state-provided seed funding or a network of accredited angel investors
Texas	Texas Capital Network	Mentoring organization and angel-investor network spun off from the IC2 Institute at UT-Austin
	San Antonio Technology Accelerator Initiative	Networking and finance initiative with 1,100 members
Utah	Wayne Brown Institute	Independent nonprofit providing mentoring and sponsoring annual equity capital conference

A common refrain in many states and regions is that, while "referral" mechanisms for start-ups abound, organizations with serial entrepreneurial management experience in the biosciences are scarce. Currently, Arizona does not have a staffed group or organization that includes experienced managers with expertise in those areas generally found to be the most important to bioscience firms—regulatory, marketing, and management. Unfortunately, most organizations lack sufficient resources to hire such experienced personnel, resulting in serving simply as referral agents.

Programmatic Description: A comprehensive Arizona Bioscience Entrepreneurial Assistance Center is proposed that not only provides in-depth assistance to bioscience entrepreneurs in the areas of capital, marketing, regulatory, and management, but is staffed by several seasoned entrepreneurial managers whose responsibilities also include management of the Arizona BioSeed Fund (see Strategy Two, Action Three) and the Technology Commercialization Prototype Development Fund (see Strategy Two, Action Two). Managing these two funds will help offset the costs of senior management personnel so that they can offer the needed expertise to Arizona bioscience entrepreneurs. Satellite offices should be established in each major region, with a statewide entity responsible for linking efforts.

Given Arizona's proximity to San Diego, it may be possible to attract several experienced bioscience entrepreneurs to Arizona to manage this set of three inter-related functions.

Resources Required: Ongoing operational costs would normally be approximately $900,000 per year for this level of personnel and experience. However, by sharing these operating costs with the BioSeed Fund and Technology Commercialization Prototype Development Fund, costs would probably range from $400,000 to $600,000 per year.

Time Frame: Immediate to short-term

Lead Organization: The BioSeed Fund, Technology Commercialization Prototype Development Fund, and general entrepreneurial management support should be located within the same organization. While these functions could be part of the Arizona Bioscience Research

Alliance, they do not need to be. If desired, a separate for-profit entity could be created to handle these functions**.**

Action Two: Support prototype development and proof-of-concept activities from research to commercialization.

Rationale: Research organizations receive substantial funding support from the federal government and, to a more limited extent, states, industry, foundations, and others. Much of this work leads to publishable papers and final reports to their funding agency. Therefore, a potential treatment, diagnosis, device, or similar product or process, unintended by the research but beneficial, may go undisclosed unless support is provided to further develop the idea or approach, conduct further applied research, undertake due diligence, or expose the research to other people with differing perspectives. These types of functions are generally addressed by prototype development/proof-of-concept funds.

Some university and medical centers have established independent entities to commercialize the institution's research findings. Baylor College of Medicine's Technologies (BCMT) unit has set the standard for captive commercialization companies owned by life-science universities. A wholly owned for-profit subsidiary of the college, BCMT invests its capital at the pre-seed stage in formation of spin-offs intended to commercialize technology owned by the college.

BCMT is a practitioner of the same "virtual company" model of spin-off formation that was pioneered by the ARCH Development Company at the University of Chicago. BCMT conducts early-stage business planning for these spin-offs, provides interim management services, recruits the first outside management team, and helps structure the first-stage venture deal (in which the college itself and local angel investors may participate at their option).

Other universities, while not going so far as to create a commercialization company, recognize the need to develop more value in intellectual property before it is licensed. They have created a range of vehicles to fund in-house commercialization research, including prototype production, that would not be fundable through peer review. Table 16 summarizes commercialization initiatives in the benchmark states.

Already, Arizona State University is using a small portion of its 301 state funds to establish a proof-of-concept fund.

Programmatic Description: It is proposed that Arizona establish a Technology Commercialization Prototype Development Fund to make $25,000 to $100,000 investments in due diligence, consultant review, applications research including prototype development, and related areas in the biosciences**.** Ideally, this fund would be available to examine unsponsored research not only in the research universities but other research organizations in Arizona, including hospitals, research centers, and industry research labs.

On a case-by-case basis, the center would determine the need for due diligence, prototype development, or proof-of-concept work by an investigator; assess the level of review required; and undertake such a review. In instances where this resulted in an improved patent/license, the research organization would share fees, licenses, and/or equity with the center.

Table 16. Commercialization Entities and Programs in the Benchmark States

State/Region	Entity/Program	Notes on Size/Scale
Colorado	CU Technology Transfer Roadmap	Investment of $2.5 million to increase technology transfer staff from 11 to 16, with breakeven projected in 5 years
Georgia	Georgia Research Alliance Technology Development Partnership Program	Funds proof-of-concept research
North Carolina	North Carolina Biotechnology Center Proof of Principle Commercialization Awards (<$25K)	
	North Carolina Technological Development Authority (NCTDA) Innovation Research Fund (<$25K)	
	North Carolina State Kenan Institute Technology Commercialization Clinic	Graduate students under faculty supervision assigned to assist start-ups and spin-outs
Oklahoma	Oklahoma Technology Commercialization Corp.	$1.7 million annually from Oklahoma Center for the Advancement of Science and Technology
Texas	Baylor College of Medicine BCM Technologies Inc. commercialization company	Invests in spin-outs at pre-seed stage, recruits manage-ment, prepares for 1st-round investment
	UT-Austin	$14 million earmarked for investment in expanding campus Office of Technology Licensing
Utah	University of Utah Research Foundation Technology Innovation Grant Fund (<$35K/year for up to 2 years)	Funded from proceeds of University of Utah Research Park

Resources Required: An outside investment of $12 to $15 million in this fund would be needed through a combination of public, university, and philanthropic support. Because of limited likely return on investment, this program would need to be re-invested every five years.

Time Frame: Short-term

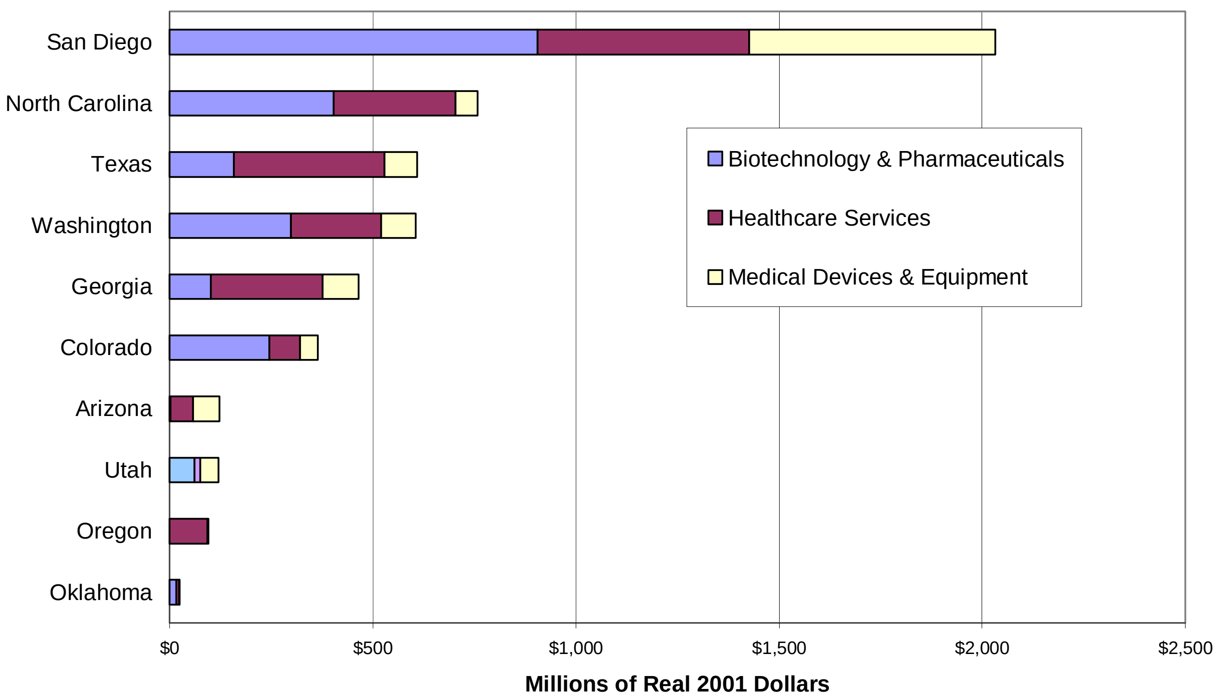
Lead Organization: This program would be run by the Arizona Entrepreneurial Assistance Center, also responsible for the BioSeed Fund.

Action Three: Invest at earliest stages of firm formation through an Arizona BioSeed Fund.

Rationale: Access to early-stage risk capital is a critical factor in building a bioscience-driven economy. One characteristic shared by leading bioscience states is that they are home to a venture capital community committed to early-stage local investment. These states also have networks of successful entrepreneurs who act as angel investors, willing to invest in very early stage start-up companies. Building a base of angel investors and venture capital funds able and willing to invest in emerging companies is a challenge for many states. Available financing also is critical for each stage of development from early-stage, proof-of-concept, and prototype development to venture financing. Leading technology states typically have access to commercialization funding, pre-seed and seed funding, and later stage venture financing.

Arizona companies are not competitive in terms of acquiring bioscience venture capital dollars in comparison to their benchmarked peers. Over the last five years for which venture capital data are available, San Diego has far exceeded the other benchmark states in capturing bio-science-related venture capital investment, securing over $2 billion (Figure 16). Arizona, with $122.7 million, is seventh among the benchmarks. It is important to note that nearly all of the venture capital deals in the state were focused on the medical and healthcare subsectors, rather than biotechnology.

Figure 16. Bioscience Venture Capital (1997–2000)



Source: PriceWaterhouseCoopers *MoneyTree* survey.

Other states and regions have shown that, unless local efforts address the pre-seed/seed stage of investment ($200,000 to $2 million), sources of later rounds of financing needed by bioscience firms are not likely to materialize, resulting in the firms leaving that state or region to go where both early and later stages of financing are available. A local lead fund attracts later stage venture firms to a region. While this is the initial suggestion for Arizona, should the state successfully build a critical mass of firms and see a significant level of bioscience enterprises in the long term, it also must address ways to build privately managed venture funds specializing in the biosciences at later stages, something that may be more attractive to public pension fund managers.

Programmatic Description: Arizona must establish a BioSeed Fund focusing on the earliest stage investments for bioscience start-ups. The average investment in any one firm at this stage is likely to be in the $200,000 to $2 million range.

While there seems to be increased interest in addressing the equity financing gap—and not all entrepreneurs and investors are convinced that there is a gap—it does appear that more firms would be created with additional resources available. If Arizona is to build a critical mass of bioscience enterprises, efforts must be undertaken that can “jump start” not only the research base but the industry base as well. While Arizona’s ability to create establishments in general has been relatively robust, it has not been as successful in building firms with significant employment in the biosciences. Access to pre-seed/seed capital is one issue that can help address this problem.

Resources Required: A fund should have up to $70 million for investment, not all necessarily at the pre-seed/seed stage. Potential sources of investors include private individuals, philanthropic sources (as endowment investments, not grants), public and private pension funds, and venture capitalists interested in the potential Arizona offers.

Time Frame: Short-term

Lead Organization: This program would be run by the Arizona Entrepreneurial Assistance Center, also responsible for the Technology Commercialization Prototype Development Fund.

Action Four: Provide wet-lab space through support of bioscience accelerators/incubators/ wet-lab space in and around research parks.

Rationale: Like capital markets, commercial real estate markets do not tend to supply (of their own accord) what bioscience firms need to grow: namely, inexpensive, wet-lab-equipped space zoned for research and process scale-up but situated very close to the research institutions and their key faculty who may serve as consultants or advisors. Given the high capital costs involved in constructing permitted laboratory space, candidate parcels are often considered to have some other higher and better use, judging by risk-adjusted expected returns. Almost any developer will eagerly build wet-lab space for a credit-worthy single tenant (assuming available land and zoning); but, barring the exceptional inward recruitment of a major biotechnology firm, this is not the issue facing most communities trying to build a bioscience cluster. Rather, the problem lies in financing incubator and multitenant space, where the tenants are not creditworthy and the concept has not been proved in the regional real estate marketplace.

Most of the benchmarks have created one or more technology-oriented research parks and/or technology incubators, several of which are focused exclusively on bioscience firms (Table 17). These parks and incubators, which are often university affiliated, have forged several successful economic development partnerships within the benchmark set. Most of the developments involve some type of public subsidy, either capital (land, mortgage, building construction) or operating (cash flow from incubators, loan guarantees, commitments to surge-space rental, etc.). These facilities have been developed in a wide range of cities and suburbs.

Table 17. Specialized Facilities in Benchmarks

State	Initiative	Status of Bioscience	Comment
Colorado	Colorado Bioscience Park Aurora	Exclusive focus	Being developed as part of the Fitzsimons Redevelopment Project, it includes incubator development.
Georgia	Advanced Technology Development Center	Primarily focused on IT, but includes some bioscience companies	Business incubator.
	Center for Applied Genetics Technology	Exclusive focus	Operated by UGA. One building constructed, two more under development. Buildings contain labs, core facilities, and space for start-up companies.
	EMTech Biotechnology Development, Inc.	Exclusive focus	Joint venture between Emory and Georgia Tech.
	CollabTech	Exclusive focus	Operated by Georgia State University.
North Carolina	Research Triangle Park, including First Flight Venture Center (incubator)	Significant but not exclusive focus	State-supported comprehensive research park, including a wet-lab incubator sponsored by the North Carolina Technological Development Authority.
	Centennial Campus of NC State University including Entrepreneurial Development Center (incubator)	One of several fields targeted	Master-planned as integrated campus/research park, including a wet-lab incubator sponsored by NCTDA.
	Piedmont Triad Research Park	Significant but not exclusive focus	Troubled project. Note also that University Research Park at Charlotte is not a true research park, but a real-estate development for the benefit of UNC-Charlotte.
Oklahoma	Oklahoma Health Research Park, which includes the Oklahoma Biomedical Accelerator	Exclusive focus	Biomedical research park and incubator developed by city and Medical Technology Research Authority.

Table 17. Specialized Facilities in Benchmarks (continued)

State	Initiative	Status of Bioscience	Comment
Oregon	Portland Biotechnology Center	Exclusive focus	Wet-lab and shared-use facility.
Texas	Houston Technology Center	One of several fields targeted	Nonprofit located downtown.
	Texas Medical Center in Houston (700 acres)	Exclusive focus	Clinical, research, and institutional uses.
	Southeast Texas Biotechnology Research Park in Houston (planned for 64 acres)	Exclusive focus	Planned for directly adjacent to Medical Center.
	Technology Research Park in San Antonio (1,236 acres)	Exclusive focus	Anchored by UT Institute for Biotechnology. Includes incubator.
	TESKA Innovations Corporation	Exclusive focus	Incubator focusing on commercialization and technology transfer from laboratories across the state.
Utah	Utah State University Research and Technology Park	One of several fields targeted	Anchored by university.
	Utah State University Biotechnology Center	Exclusive focus	Bioprocess facility provides shared core resource service labs.
Washington	Washington Research Foundation Venture Center	One of several fields targeted	Owned by WRF, independent nonprofit. Research park and university-affiliated incubator are also under discussion.

In recent months, the Tucson Technology Incubator opened a new site with wet-lab space. However, a similar bioscience incubator does not exist in Phoenix or elsewhere in the state.

Programmatic Description: There are two related initiatives under this action:

- Addressing the need for incubator/accelerator space in Tucson and Phoenix.
- Addressing the need for wet-lab space for bioscience firms in Arizona.

Incubator/Accelerator. It is proposed that comprehensive bioscience incubators/accelerators be developed in Tucson and Phoenix in the next several years, with others to follow as a critical mass is generated. Incubators/accelerators are to biosciences what "spec buildings" were to industrial recruiters in the post-World War II era. Ideally, such facilities need to be closely located or co-located with research anchors, whether those of a university, medical center, or some combination thereof. Increasingly across the United States, incubators and accelerators anchor university-related research parks, thereby providing an important place to locate both spin-offs and firms wishing to work closely with a medical or academic center.

The plans to locate TGen and IGC in downtown Phoenix provide an excellent opportunity to include an incubator and accelerator as part of the same complex. This would provide an entrepreneurial anchor for the Medical School expansion and for UA and ASU plans to increase their presence along with that of TGen and IGC.

Connecticut Bioscience Facilities Fund

The $40 million in its Connecticut Bioscience Facilities Fund is managed by Connecticut Innovations, Inc., on a deal-by-deal basis, structuring financing to meet the specific situation. The fund has provided direct-loan financing for tenant wet-lab improvements, structured a loan loss reserve fund to enable developers to acquire private financing, and provided innovative equity/direct-loan financing packages. Also, it is often an equity investor in the biotechnology firms that it lends to for tenant improvements. To date, the Bioscience Facilities Fund has assisted in creating 200,000 square feet of laboratory space and closed on $18.5 million in financing.

Wet-Lab Space for Bioscience Firms. As stated earlier, it is difficult to convince private develpers to build wet-lab space, in part due to the concerns of their financiers about what happens if a firm leaves. To help overcome this barrier, Connecticut Innovations' Bioscience Facilities Fund and Maryland's Sunny Day Fund both make loans to bioscience firms, or in Connecticut's case to private developers, for the "leasehold improvements" needed to provide labs, special air and water, and related facilities. These programs operate on the assumption that, if the beneficiary tenant becomes financially troubled, these key improvements can be made available to another, second wave of tenants once possession of the lease has been secured. In effect, it becomes part of the permanent infrastructure of the state whether or not the initial beneficiary of the program survives. Similarly, Arkansas has a tax credit program to encourage private developers.

The advent of TGen\IGC may represent an opportunity for local and state economic development officials to develop a program similar to that of Connecticut, Arkansas, or Maryland to address over the next several years the already identified shortage of wet-lab space in Arizona.

Resources Required: There is a considerable range of costs for developing incubators and accelerators. Such facilities, depending on size, could range from $7 million to $10 million or more for the incubator portion alone. Multitenant accelerator space, depending on size, could range from $10 to $20 million. In addition, if one or more of these facilities were collocated in a research park or similar entity, there may be associated costs of collocating a research anchor with the incubator and accelerator. Costs of addressing and providing incentives for the private sector to construct sufficient wet-lab space in research parks and related infrastructure could range from to $40 to $50 million over the next five years. Consequently, depending on the exact scenario, the estimated range for incubator/accelerator/research park/wet-lab space is $90 to $120 million. The public sector, including local governments, in partnership with philanthropic and private sector interests need to step forward to address the real estate development costs of building a bioscience-driven industry base. Linking incubators with the need for multitenant wet-lab space may secure private support to "invest" in the multitenant portion of such mixed-use facilities or complexes. State and local governments in Arizona need to think of creative ways to use local and state support in concert with private and philanthropic interests to address this technology infrastructure need.

Time Frame: Short-term

Lead Organization: The lead organization may vary with the site selected.

Action Five: Provide a mechanism for Arizona universities to take equity in start-up companies.

Rationale: Cutting-edge university technology transfer programs aggressively pursue patenting, licensing, and faculty disclosures. They encourage spin-offs, where justified, as well as licensing with fee and royalty payments. But, such functions also are being expanded to technology commercialization. Arizona's public research universities are hamstrung by ambiguity concerning whether and how they can take an equity position in firms formed around their licensing functions. In recent years, the best practices among the nation's leading universities have encouraged and supported universities moving away from simply taking an up-front fee and ongoing royalty payments to universities taking equity in the firm. The nation's leading medical centers and research universities recognize that equity is an important alternative approach in their technology transfer function. Yet, Arizona remains unclear as to whether its universities can or cannot do this. Because those universities receiving major "home runs" either in equity or royalty and fees have done so almost always as the result of bioscience research, the resolution of this issue is important to the state's bioscience community, including investors, faculty, universities, and the state government.

Programmatic Description: The State of Arizona must resolve in the near term the issue of whether university technology transfer arrangements permit universities, directly or indirectly, to take equity in firms receiving a license from the university. Because this issue has remained unresolved for so long, it is appropriate that it receive immediate attention and resolution, either through permitting and allowing universities to take equity through a third party, e.g., university foundation, or by Constitutional Amendment. If it is to be resolved through a Constitutional Amendment, then the Governor and Legislature should place such an amendment on the ballot as soon as possible.

Resources Required: Staff time to resolve

Time Frame: Immediate

Lead Organization: Governor and Legislature working with public research university leadership.

Strategy Three: Offer a business climate and environment that supports, sustains, and encourages the growth of bioscience enterprises, small and large, to start, expand, and remain in Arizona

Lessons learned from best practices around the nation verify that bioscience-based economies thrive in a stable and supportive business environment. Generally, business climate refers to items such as tax policy, regulatory climate, economic incentives, quality of life, costs of doing business, real estate, and general business leadership. Technology-intensive companies need a tax environment that values their contribution to economic health and recognizes their specific requirements. Policies that recognize the long development cycle in bioscience technology can help firms maintain a sound capital structure and ensure a level playing field with respect to old economy industries.

This strategy does not attempt to address all business issues affecting, Arizona but zeros in on the most critical business climate issues directly relevant to the biosciences.

Tactics

The following tactics should be pursued to create a business climate in Arizona that will lead to creation, growth, and retention of bioscience firms:

- Re-examine the state's economic development tool kit, including tax codes and incentives and technology zones, to ensure that they encourage long-term investments in the state's bioscience industry and treat the industry the same as other industries.
- Encourage an active industry-led set of trade associations supportive of the bioscience industry.
- Build an image and story of Arizona around the biosciences.

Strengths on which to Build

- Business environment that is conducive to development
- High quality of life in terms of cultural and recreational amenities, climate, and affordability

Weaknesses to Overcome

- Few economic development assistance programs
- Unfavorable tax structure
- Severe budget constraints
- Business service providers not strongly specialized in the biosciences
- No image as a high-tech center

Opportunities on which to Capitalize

- Opportunity to create a bioscience corridor – Flagstaff to Tucson
- Proximity to other markets provides a unique comparative advantage, e.g., San Diego and Mexico

Threats to Minimize

- Arizona's leaders may have unrealistic expectations and fail to recognize that developing the biosciences will require a patient and long-term commitment

Actions for Strategy Three

It is proposed that Arizona pursue several actions as part of its broader business climate incentives that will make Arizona and its communities conducive to the growth and development of bioscience firms. The following actions are included under Strategy Three:

Action One: Revise state/local economic development programs and the state's tax code to support the growth, expansion, and selective recruitment of bioscience firms.

Action Two: Establish Technology Zones around existing and proposed concentrations of bioscience and other technology industries.

Action Three: Form regional bioscience technology councils as separate organizations or as part of a broader regional technology council.

Action Four: Initiate a statewide image, marketing, and business development effort to market Arizona as a location for bioscience firms.

Action One: Revise state/local economic development programs and the state's tax code to support the growth, expansion, and selective recruitment of bioscience firms.

Rationale: States traditionally have used tax policy to encourage companies to locate or grow within the region. Many development incentives, however, provide a subsidy or credit based on employment levels, and as such tend not to benefit bioscience and technology companies that have small numbers of employees but high intellectual capital. Some states are enacting changes in tax policy designed to provide benefits to technology firms, including bioscience firms.

No state among the benchmarks has implemented tax incentives or regulatory reform aimed specifically or exclusively at bioscience companies; but, virtually all have determined that bioscience sectors are included among those targeted by initiatives aimed at R&D in general (Table 18). Typical tax initiatives include the following:

- Treatment of R&D equipment on a par with manufacturing equipment with respect to exemptions or abatements from sales or use tax on its purchase
- Treatment of R&D equipment on a par with manufacturing equipment with respect to exemptions or abatements from tax on its value as tangible personal property (where such tax is levied on businesses)
- Tax credits for R&D expenditure—either incremental of a baseline or non-incremental—and carryforward and/or sale of unused credits.

Table 18. Tax Policies Enacted in Benchmarks

State/Region	Initiative
Colorado	R&D tax credit for Enterprise Zone; investment tax credit; sales and use tax refund; rural technology Enterprise Zone credit
Georgia	Research expense tax credit is allowed for research conducted
North Carolina	R&D tax credit; abatement on machinery and equipment; job expansion tax credit.
Oklahoma	Tax credits for venture capital investment; sales and use tax refunds; ad valorem tax exemptions
Oregon	Qualified research activities credit and alternative credit; property tax exemption
San Diego	Manufacturers' investment credit; R&D tax credit; NOL carryover
Texas	R&D tax credits and business loss carryovers; job creation tax credit; capital investment credit
Utah	Credits for machinery or equipment used for conducting R&D; credits for research activities conducted in state
Washington	Job creation tax credit; sales and use tax exemption for R&D equipment and constructing research facilities; high-technology sales and use tax deferral or exemption and occupation tax

The "economic development tool kit" traditionally available to all industries may not be appropriate or address the concerns of bioscience firms whose interests include workforce/customized job training programs, matching partnerships with academic health centers and universities, and local equity funds that can serve as early-stage investors. Because its tool kit is small to begin with, Arizona is in a good position to re-examine its few incentives and other programs to determine how they might be adjusted to better serve the biosciences. In addition, the state and local jurisdictions also may need to review state and local tax codes and regulations to ensure equal treatment of this industry with other traditional industries in the state.

A more fundamental problem Arizona must address is a tax structure that, while serving the state well in the past, is not designed to encourage a diversified economy that treats businesses and individuals fairly; encourages business investments; encourages businesses offering good, well-paying jobs; and provides the state with sufficient revenues to ensure both an adequate K-12 education system and a strong research-driven higher education system. Arizona ranks poorly on most of these education investment measures and will need to comprehensively address tax reform if it is going to ultimately address the quality of its K-12 and higher education systems.

Programmatic Description: The state needs to undertake a comprehensive review of its economic development programs, including tax incentives, and modernize its tax code and adequately invest in K-12 and higher education. While the state's economic development incentives are limited, it needs to clearly look at current credits and programs to ensure that they are designed to service industries such as the biosciences in the future and to design a tax structure that both serves the bioscience industry and provides the revenue base to invest in both K-12 and higher education.

Resources Required: A review of state incentives and tax structure expected with the support of business, higher education, and other sectors should cost in the range of $500,000 to $750,000.

Time Frame: Short-term

Lead Organization: Governor and Legislature, in coordination with interested and affected parties.

Action Two: Establish Technology Zones around existing and proposed concentrations of bioscience and other technology industries.

Rationale: Bioscience firms tend to concentrate geographically in or near bioscience anchors, usually universities and medical centers, or other research anchors, such as TGen and IGC will provide in Arizona. Because of this desire for geographical proximity, local governments can affect these efforts by offering tax, regulatory, permitting, and other incentives to firms that locate near one another. Some call these "technology zones," similar to enterprise or empowerment zones in terms of concept, although the incentives important to bioscience firms may be considerably different than those offered to firms settling in disadvantaged neighborhoods. In addition, some states have used tax increment financing to enable the zone to capture increased taxes (resulting from those paid by entities located in the zone) to build additional infrastructure such as incubators and accelerators.

Programmatic Description: It is proposed that Arizona's state and local governments examine and consider administrative and statutory changes to allow for the establishment of four to six bioscience technology zones located near universities or medical centers. In addition to providing incentives such as one-stop permitting and regulatory assistance, recognition and understanding of hazardous waste regulations as they affect bioscience facilities, and transfer/selling of tax losses for cash, the zones could be allowed to use tax increment financing to finance improvements in the zone.

Resources Required: Administrative and statutory action

Time Frame: Short-term

Lead Organization: Economic development officials at local and state levels

Action Three: Form regional bioscience technology councils as separate organizations or as part of a broader regional technology council.

Rationale: Unlike traditional manufacturing, technology-driven firms, most particularly bioscience firms, relish networking opportunities and seek collaborators. Bioscience executives are interested in learning more about what is going on in various research organizations, in the industry as a whole, and trends and developments. Mature and emerging states and regions trying to build a "critical mass" of bioscience firms have found that the scale and intensity of networking must be considerable, large, and multiple to lead to value-added relationships. Arizona suffers from a fragmentation of organizations, having established organizations around six industry clusters in both southern Arizona and Phoenix. Two bioscience industry associations are the Arizona Bioscience Industry Association, based in Phoenix, and the Bio Industry Association of Southern Arizona, based in Tucson. Neither of these organizations have the staff or resources to provide in-depth assistance to bioscience firms or to facilitate intensive networking.

A number of states, including Pennsylvania, Maryland, New Jersey, and New York, have had border-to-border, broad crosscutting technology councils serving not only the biosciences, but information technologies and other industries. Other states such as Massachusetts, California, and Washington have had statewide and/or regional technology councils organized by industry sector, e.g., biosciences, IT, etc. Arizona historically organized itself by cluster/industry; although, in recent months, two new cross-cutting technology councils have emerged, the Arizona High Technology Council in Phoenix and the Southern Arizona Technology Council in Tucson.

Programmatic Description: It is proposed that Arizona form regional bioscience organizations in both Tucson and Phoenix and together have them function as a virtual statewide group over the next several years**.** The current situation is serving no one well. Because of the distance between the two cities, it may make more sense to create networking and advocacy groups regionally; together they can serve as a virtual statewide advocate, at least until a larger mass of firms is formed. Alternatively, these two regional associations could associate with the Arizona High Technology Council and the Southern Arizona Technology Council.

The leadership of these regional organizations, to the extent possible, should be vested in leaders from the bioscience industry, not academe, economic development, or service providers. While all important to the councils' success, these do not have the same motivations as private firms that, first and foremost, must be the intended beneficiaries of the activities and functions of these organizations.

Resources Required: The state government can support and give credibility to these regional organizations, encourage their focus and geographical coverage, and encourage them to work together on common issues. In some states, seed funds have been provided that have a declining funding basis over several years to establish such organizations.

Time Frame: Short-term

Lead Organization: Industry and regional technology organizations

Action Four: Initiate a statewide image, marketing, and business development effort to market Arizona as a location for bioscience firms.

Rationale: To attract talent, entrepreneurs, and others, states must be perceived as places where technology development and innovation are happening. Arizona has historically developed a subdued image in technology assembly-line manufacturing, but even this has been somewhat overshadowed by its image as a travel and tourist destination and as a retirement center. A recent national survey by one regional economic development organization confirmed Arizona's weak perception outside the state as a technology center.

Building an image and a brand for Arizona in the biosciences must go hand in hand with its strengths and strategies. Consequently, an important early step is to brand Arizona around its technology platforms and strategies, i.e., quality health care and excellent research in cancer, the neurosciences, and bioengineering. In addition, the branding must be field tested inside and outside the state. Whatever is gained from these efforts must then stand the test of time. It was indicated earlier that building a bioscience base takes long-term commitment and patience—so, too, will branding and marketing.

Programmatic Description: Arizona's Department of Commerce, in conjunction with local economic development groups, should develop both a brand name and a marketing strategy, refocusing its existing marketing efforts to target the biosciences. To some extent, these efforts are already underway, including unprecedented sharing of marketing strategies across regions of the state, an important first step. One early target, based on the experience of TGen/IGC, is to recruit research organizations to Arizona.

Resources Required: Use existing resources, now used for general marketing, but refocused on the biosciences.

Time Frame: Long-term

Lead Organization: Bioindustry Development Team formed by the Department of Commerce, local economic development organizations, the Flinn Foundation, and other interested parties.

STRATEGY FOUR: ENCOURAGE THE STATE'S CITIZENS TO BECOME A MORE INFORMED CITIZENRY IN THE BIOSCIENCES AND ENCOURAGE YOUNG PEOPLE TO EXPLORE AND PURSUE SCIENTIFIC AND TECHNICAL CAREERS

Leading bioscience states have illustrated that a supply of qualified, technology-trained workers is critical to the development and sustainability of a bioscience-based economy. Competing in the knowledge economy requires a population that is both highly educated and committed to life-long learning. Successful states and regions educate their citizens at a rate well above the average, attract educated individuals from other states, and have in place mechanisms for the continued education of workers at all levels. The bioscience industry requires a supply of qualified, trained workers at all levels. Successful states maintain adequate supplies of not only doctoral-level researchers, but also technicians with two-year degrees and managers ranging from entrepreneurs themselves through mid- to senior-level executives who are comfortable with high-technology settings. States without a deep, natural pool of talent use a variety of tools, including formal university curricula, marketing programs aimed at worker retention, and peer-support for entrepreneurs.

If Arizona wants to build a dynamic competitive bioscience base, it must have a ready, capable and skilled talent base from technician to postdoctoral level of educational attainment available. Arizona's K-12 quality issues, raised again and again with the Battelle Team, must be addressed. Otherwise, the only way Arizona can compete in the biosciences will be through in-migration of talent. Given its quality of life, weather, relative distance to San Diego, and other factors, the state can probably attract migrating talent as successfully as it has since World War II. However, it fails to take full advantage of its internal human resource base and does not offer opportunities for well-paying jobs for its citizens. The purpose of this study, however, is not to review and recommend changes in Arizona's K-12 system; for this reason, these actions are focused directly on those areas that are critical to the biosciences and their development in the state.

Strengths on which to Build

- Community colleges and universities offering bioscience curricula

Weaknesses to Overcome

- Lack of certain skilled bioscience workers

Opportunities on which to Capitalize

- Arizona's educational institutions are increasingly producing more graduates in the biosciences

Threats to Minimize

- Arizona's leaders may have unrealistic expectations and fail to recognize that developing the biosciences will require a patient and long-term commitment

A severe gap has emerged throughout the country between public training and employment services programs and the human resource development strategies and operations of firms. For the most part, bioscience firms ignore these programs.

Most states with ambitions in the biosciences have recognized that companies in this industry set have specialized requirements for workforce training and a strong interest in operating in environments where there is good public understanding of the biosciences. Efforts have focused to date mainly on the development of curricula and teacher-training programs for the K-12 sector, although some states are adding university-level curricula and/or adjusting their customized job-training programs to focus more on the needs of bioscience firms (Table 19).

Tactics

Ways to position Arizona in its talent base and future talent pool include the following:

- *Being a leading state where new interdisciplinary programs representing the cutting edge of biosciences are first offered*. Having the talent pools in new fields will attract and grow the bioscience industry in Arizona.
- *Offering lifelong bioscience career ladders connecting career education, community colleges, undergraduate, and graduate degrees in a seamless web of articulation*, enabling the state's workforce to be lifelong bioscience learners.
- *Assuring that K-12 education is encouraging students to pursue bioscience careers and all students are biology knowledgeable.*

Table 19. Summary of Bioscience Training Programs in the Benchmark States

State/Region	Entity/Program	Notes on Size/Scale
Colorado	Colorado Institute of Technology	Annual support from industry funds for development of new curricula, now including biocomputation
Georgia	HOPE Scholarships	Lottery-funded scholarships aimed at in-state retention of good students across many disciplines
	University System of Georgia Intellectual Capital Access Program	Vehicle for customized training, curriculum development, etc.
North Carolina	North Carolina Biotechnology Center Education Enhancement Grants	Minigrants for K-12 curriculum development on biotechnology
	North Carolina Biotechnology Center Summer MBA Internships	Pays salaries of first-year MBA students placed with bio-technology firms, up to 220 work hours
	North Carolina School of Science and Mathematics at Durham	Two-year-residential charter school 80% state-supported, balance raised from parents, alumni, foundations, companies
Oklahoma	Oklahoma Center for Advancement of Science and Technology Internships	Up to $50K to place faculty and students at Oklahoma businesses for up to two years
Washington	University of Washington Dept. of Molecular Biotechnology Outreach Program	Directly offers hands-on programs on biotechnology for K-12 students and their teachers

Actions for Strategy Four

To encourage the citizenry to be more knowledgeable about science and technology, including careers and applications to daily living, improvements are needed in science and math in K-12, the capacity to understand and address health policy issues, and retaining talent in the state through co-op and internship programs. Finally, to build its research reputation, Arizona needs to attract the top graduate students to clinical research opportunities in the state. Three actions are proposed to address these issues:

Action One: Create capacity to understand and address health policy issues from review boards and central data banks to ethics and public policy reviews.

Action Two: Address the state's future talent pool by making improvements in science and math in K-12 through graduate education.

Action Three: Encourage talent to remain in the state by expanding co-op and internship programs.

Action One: Create capacity to understand and address health policy issues from review boards and central data banks to ethics and public policy reviews.

Rationale: To further build Arizona's capacities in the biosciences, a range of health policy issues will need to be addressed over time. Its several distinct population groups—senior citizens, Hispanics, and Native Americans—offer the potential to build databases for genomics/bioinformatics work that will provide the state a distinct advantage over others. However, the state must also have in place the clinical research capacities to handle clinical trials, tissue banks, etc., already being started with the establishment of the Arizona Research Consortium. Regulatory approaches including review board protocols will need to be receptive to such efforts.

Programmatic Description: Arizona will need to take advantage of its unique population characteristics and encourage and support clinical trials, clinical research, and create a legislative environment in which these efforts can be undertaken.

Resources Required: $3 million per year. Supportive environment needs to be offered by state government.

Time Frame: Long-term

Lead Organization: State, higher education, and medical centers

Action Two: Address future talent pool by making improvements in science and math in K-12 through graduate education.

Rationale: While Arizona's entire K-12 educational system needs major quality improvements if the state is to keep and attract talent, value-added firms, and other enterprises, this Roadmap does not purport to lay out a strategy for K-12. Rather, because talent is becoming an increasingly important differentiating factor, Arizona must address changes in workforce and education policy that make the state more attractive for the growth of bioscience research, quality health care, and job generation.

Programmatic Description: Several initiatives are suggested under this action:

- Initiate and implement changes in curriculum to address new and emerging interdisciplinary fields, including career path linkages to career education (K-12), community college technician training, and undergraduate and graduate degrees.
- Offer education and training support for K-12 science teachers in the biosciences.
- Consider loan forgiveness scholarship programs for students pursuing undergraduate and graduate education in key bioscience fields and emerging disciplines.

These initiatives will encourage K-12 students to be knowledgeable of the biosciences, increase interest in pursuing college bioscience degrees and programs, and encourage Arizona to offer cutting-edge interdisciplinary programs that provide the state a comparative advantage in its future talent pool of graduates.

Resources Required: The resources for each of these initiatives include the following:

- Initiate and implement changes in curriculum: $250,000 to $500,000 one-time funding.
- Offer education and training support for K-12 science teachers in the biosciences: $1 to $2 million per year.
- Consider loan forgiveness to scholarship programs for students pursuing undergraduate and graduate education in key bioscience fields and emerging disciplines: depending on eligibility $5 to $25 million per year when fully implemented.

Time Frame: Long-term

Lead Organization: Governor, Legislature, and education leaders

Action Three: Encourage talent to remain in the state by expanding co-op and internship programs.

Rationale: Arizona has historically attracted its talent by importation. It needs to continue to keep its best students in the state and make graduates aware of job opportunities within Arizona. Internship programs in the biosciences and co-op programs in bioengineering and related fields will help Arizona students learn more about Arizona employers and job opportunities available prior to graduation.

Programmatic Description: Arizona should establish a large-scale internship program with employers and education institutions in the biosciences. It also should consider co-op programs in engineering with a particular focus on bioengineering. Internship programs need to be much more systematic, with a focus by bioscience administrators and faculty on scaling up their efforts considerably. The regional bioscience councils can help develop more formal programs and find job placement opportunities for the students.

Resources Required: Costs of internship programs and co-op programs are primarily borne by employers, but coordination costs could range from $200,000 to $500,000 among all parties.

Time Frame: Long-term

Lead Organization: Regional bioscience councils in concert with Arizona Bioscience Research Alliance

SUMMARY

This section of the report proposed that the vision for Arizona's future in the biosciences be achieved through the execution of four strategies involving 19 actions. These actions are designed to leverage significant private and other funds. Many are one-time actions that, if successful, will enable the private sector to move forward without need for ongoing renewal of public investments. Other investments are annual and long term, such as building the state's higher education research and development base.

Figure 17 illustrates how these various actions address, in a logical and systematic fashion, the gaps facing Arizona in becoming a leader in the biosciences. Each of the actions proposed is linked systematically to other actions, and the entire set of strategies is designed to help position Arizona strategically. It is envisioned that public dollars will leverage significant private, philanthropic, and federal funds. This strategy is intended to be driven by industrial needs. As such, state funding should be utilized to fill the gaps for projects and initiatives that are being driven by nonstate resources.

Figure 17. Proposed Actions in Arizona's Strategic Continuum

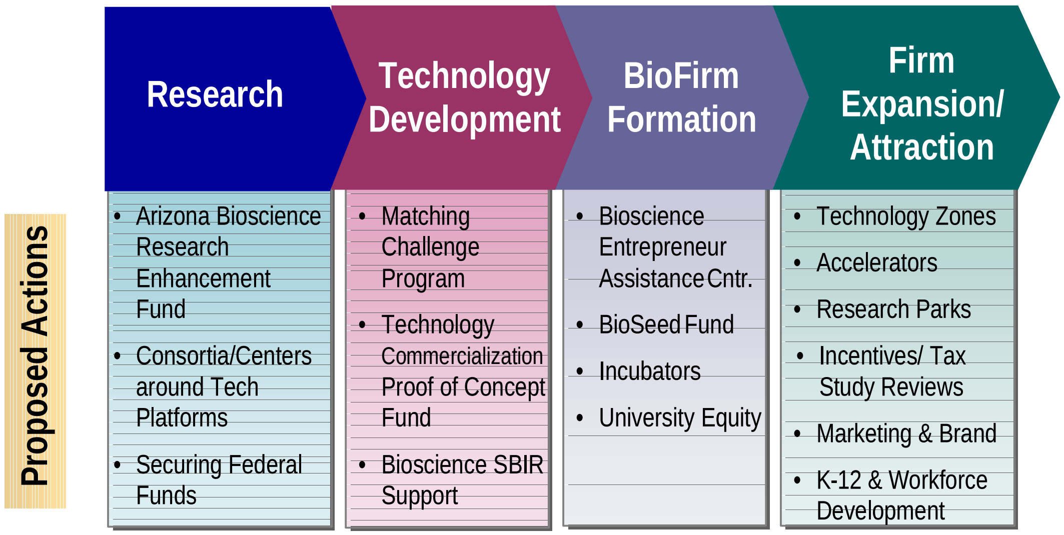


Table 20 links Arizona's current situation to the lessons learned in the best practices and outlines how the recommended actions, if implemented, will address the current gaps within the state in line with the best practices across the nation.

Table 20. Proposed Actions in the Context of Arizona's Current Situation

Factors of Success	Arizona Situation	Recommended Actions
Engaged Universities with Active Leadership	✓ The leadership of Arizona's universities is committed to developing the bio-sciences and has entered into partnerships such as TGen ✓ Improvements have been made in technology transfer and commercial-ization, but greater investment is needed in vehicles for technology commercialization	✓ Arizona Bioscience Research Enhancement Fund ✓ Stimulate research collaboration among universities/hospitals/other research organizations ✓ Establish a Matching Challenge Program to connect industry and researchers
Intensive Networking	✓ There are no active, professionally staffed industry organizations that have the ability to provide networking opportunities at the scale and intensity necessary to promote the emerging bioscience firms ✓ The state's existing bioscience cluster organizations are still in an early stage of development after several false starts	✓ Form the Arizona Bioscience Research Alliance ✓ Form regional bioscience technology councils as separate organizations or as part of a broader regional technology council
Available Capital	✓ A number of Arizona-based venture funds exist, several of which are investing in bioscience companies ✓ A gap in pre-seed/seed funding stage is generally conceded ✓ Limited angel networks are investing in the biosciences	✓ Increase help to entrepreneurs to secure federal SBIR/STTR funds ✓ Invest at earliest stages of firm formation through an Arizona BioSeed Fund ✓ Provide in-depth, comprehensive, entrepreneurial assistance support to start-up and emerging bioscience companies ✓ Support prototype development and proof-of-concept activities
Discretionary R&D Funding	✓ Market share of NIH funding awards has decreased ✓ Limited success exists in obtaining federally designated bioscience centers ✓ Successful effort to attract IGC and TGen represents major accomplishment	✓ Secure federal investments to build Arizona's bioscience capacity
Talent Pool	✓ Arizona graduates are in excess of bioscience jobs available ✓ Strong interdisciplinary efforts exist at universities ✓ Strong community college system is offering increased curricula in the biosciences ✓ Weak K-12 system will limit ability to produce students who will pursue bioscience careers	✓ Address future talent pool by making improvements in science and math in K–12 through graduate education ✓ Encourage talent to remain in the state by expanding co-op and internship programs ✓ Address the need to attract top graduate students to clinical research opportunities in Arizona

Table 20. Proposed Actions in the Context of Arizona's Current Situation (continued)

Factors of Success	Arizona Situation	Recommended Actions
Specialized Facilities and Equipment	✓ Wet-lab space is insufficient ✓ No specialized bioscience research parks exist ✓ Incubator and accelerator space for bioscience companies is limited ✓ Knowledge of university equipment and facilities that could be accessed by firms is lacking	✓ Provide wet-lab space through support of bioscience accelerators/incubators/wet-lab space in and around research parks ✓ Arizona Bioscience Research Enhancement Fund
Supportive Business Climate	✓ Arizona has few economic development assistance programs to attract, retain, and grow bioscience firms ✓ Arizona's tax structure is not favorable for the development of a technology-based economy ✓ Arizona's affordability, regulatory environment, and access to resources are better than on either coast ✓ Arizona does not have an image or brand as a high-technology center	✓ Revise state/local economic development programs and the state's tax code to support the growth, expansion, and selective recruitment of bioscience firms ✓ Establish Technology Zones around existing and proposed concentrations of bioscience and other technology industries ✓ Initiate a statewide image, marketing, and business development effort to market Arizona as a location for bioscience firms
Patience and Long-term Perspective	✓ Arizona does not have a history of long-term state investment in technology development ✓ Development of successful partnerships to pursue IGC and TGen suggest that public and private leaders are beginning to make a long-term investment to building Arizona's bioscience base	✓ Create the Arizona Bioscience Research Alliance

Implementation

INTRODUCTION

The previous sections of this report assessed Arizona's position in the biosciences; addressed Arizona's core research and technology platform opportunities; benchmarked Arizona's performance against its peer states and best practice competitors; assessed the state's strengths, weaknesses, opportunities and threats, identified the gaps to be addressed; and proposed a four-strategy, 19-action program to address these gaps and improve Arizona's competitive position in the biosciences over the next 10 or more years. This section of the report lays out the major actions critical to success, the immediate priorities, the organization and structure for moving this roadmap forward, the resources required, and accountability measures of success on which to judge results.

An implementation plan for Arizona's bioscience roadmap is designed to catalyze public and private sector collaboration and private sector investment, focused on filling "market gaps" that the private sector cannot or will not undertake on its own. But, addressing gaps, while necessary, is not sufficient. The State of Arizona also must have a committed set of leaders and champions for this roadmap, particularly in helping address the state government's fundamental basic role of funding and support for both K-12 and higher education. In the future, close and careful connectivity and linkages must exist among the various efforts to build Arizona's bioscience-driven economy, including linkages of higher education, industry, and government. The biosciences are, and may continue to be in the future, a unifying force to bring Arizona's cities and regions together with the state around a common agenda, set of strategies, and directions, as laid out in this document.

The actions described in this roadmap, while requiring some public catalytic action in the initial stages, rely, for the most part, on the private and philanthropic sectors, federal funding sources, and others to achieve significant progress and impact. In many cases, the effort is focused on ensuring that private sector market gaps are addressed and sustained over the long term by private actions and private investments such as addressing the need for wet-lab space, securing pre-seed and seed venture capital, and providing support for technology commercialization.

Wherever possible, existing entities' roles and responsibilities should be expanded to implement these activities. The preference should be to reconstitute or use existing organizations and programs wherever possible in the implementation of the Roadmap. Stakeholders should be encouraged to use this approach where it makes sense in terms of both efficiencies, but equally important, in terms of achieving results.

CRITICAL ACTIONS

The successful implementation of eight activities will ultimately determine whether Arizona can competitively position itself in the biosciences. These eight critical activities are as follows:

- Form the **Arizona Bioscience Research Alliance** to serve as steward for this Roadmap's implementation, as well as possible direct operational involvement in those action items that otherwise cannot be initiated without the alliance's leadership role.
- Establish the **Arizona Bioscience Research Enhancement Fund** to provide the necessary investments in higher education research and education (e.g., endowed chairs, recruitment packages, laboratories, instruments, and faculty) for its universities to secure world-class stature in selective platform areas in collaboration with other medical, health, industry, and nonprofit research organizations.
- Form, from this Arizona Bioscience Research Enhancement Fund and federal funds, **consortia/centers in the key technology platform areas** identified in this report—neurological sciences, cancer therapeutics, and bioengineering.
- **Pursue, in concert with Arizona's Congressional Delegation, federal funds and investments** to further build the state's research enterprise.
- Establish the **Arizona BioSeed Fund** to offer an indigenous source of pre-seed and seed investments necessary to build a critical mass of homegrown bioscience firms.
- Establish the **Arizona Technology Commercialization Prototype Development Fund** to "mine" research in Arizona's research organizations to develop products and processes used by existing companies or around which new firms can be created.
- Establish the **Arizona Entrepreneurial Assistance Center** to provide in-depth mentoring and support from seasoned entrepreneurial managers (also responsible for managing the BioSeed Fund and Technology Commercialization Prototype Development Fund).
- **Provide adequate funding, including general obligation state bond financing, for higher education research facilities and laboratories.**

The biosciences address a concern of all the state's residents—access to quality health care in an environment in which the latest treatments, diagnostics, and prevention methods are practiced daily by medical and health care personnel who are outstanding clinicians, researchers, and practitioners. In addition, the biosciences provide a way to build a stronger, more stable, and diversified Arizona economy, offering quality, well-paying jobs from technician to researcher.

IMMEDIATE WORK PLAN PRIORITIES

Immediate work plan priorities are those steps the private and public sectors in Arizona should undertake in the first 12 months of strategy implementation. Several critical priorities need to be implemented right away, while others will need to be planned and allocated funds before they can become fully operational.

The following actions should be undertaken in the first year of implementing the Roadmap Alliance:

- Form the Arizona Bioscience Research Alliance to serve as a steward for this Roadmap's implementation.
- Begin the process of encouraging gubernatorial and legislative support for the Arizona Bioscience Research Enhancement Fund, possibly by administratively using state general

obligation bonding authority to fund facilities, labs, and recruitment packages for bioscience development in the key technology platform areas.

- Work with the philanthropic sector, state government, and higher education institutions, develop strategic business frameworks and investment plans for each technology platform area.
- Discuss and develop a concept plan and begin to build gubernatorial and legislative support for the formation of an Arizona Bioscience Matching Challenge Program.
- Prepare an annual list and a multiyear strategy of key bioscience projects and investments to submit to Arizona's Congressional Delegation.
- Resolve the approach necessary to enable the state's public research universities to take an equity participation in licenses.
- Develop a prospectus for the entrepreneurial assistance center.
- Begin discussions with in-state angel and other wealthy investors, the state's private and public pension and venture funds, and leaders in industry and higher education to secure capital commitments for the Arizona BioSeed Fund.
- Develop stronger regional bioscience councils, either stand-alone or part of a broader technology council, and increase the scale of networking activities for the bioscience industry.
- Use existing state and regional promotion and marketing funds to focus on making Arizona a more recognized center in the biosciences and develop Arizona's "brand name" in the biosciences.
- Begin planning for an expanded co-op and internship program**.**

RESOURCE REQUIREMENTS

Table 21 shows, for each action, the priority of the action and the annual and one-time costs. The successful effort to raise funds for TGen illustrates the level of stakeholder involvement and support across a number of private and public organizations that will be needed to successfully implement this Roadmap.

Table 21. Arizona Roadmap Resource Requirements

Action	Priority	Annual Cost	One-time Costs	Leverage Ratio
Arizona Bioscience Research Alliance	Immediate	$400,000–$500,000	0	N/A
AZ Bioscience Research Enhancement Fund	Immediate		$42 million/year for 8 years	1:9
Research collaborations, consortia, centers, and institutes	Two Immediate initiatives (TGen/IGC and ARC) Third effort years 4–6 or sooner	$10 million/year in non-federal operating support	$400 million for capital projects around platforms TGen/IGC– $90 million	1:9
Bioscience Matching Challenge Program	Immediate to short-term	Initially $750,000 rising to $6 million/year by year ten	0	1:3
Bioscience SBIR Support Program	Short-term	$400–$600,000	0	1:4
Seek federal funding with Congressional Delegation	Immediate		Goal of $170 million or more over 10 years in federal funds	1:150
Adequately fund higher education	Short-term	Use bonding authority to finance capital improvement projects		N/A
Attract graduate students	Short-term	$1.8 million/year	0	1:3
AZ Bioscience Entrepreneur Assistance Center	Immediate	$400–$600,000	0	N/A
Bioscience Technology Commercialization Prototype Development Fund	Short-term	0	$12–$15 million every five years	1:5
AZ BioSeed Fund	Short-term	0	Up to $70 million in private and other support	1:9
Incubators/accelerators and research parks	Short-term	Operating support for incubator of $150–$250,000 annually for first 18–36 months for three facilities	$50-$70 million for three incubators/ accelerators $40–$50 million for research park and related infrastructure	1:5

Table 21. Arizona Roadmap Resource Requirements (continued)

Action	Priority	Annual Cost	One-time Costs	Leverage Ratio
Mechanism to allow universities to hold equity	Immediate	No additional costs but source of additional revenues		N/A
Comprehensive review of economic development and tax policy	Short-term	0	\$500–\$750,000	N/A
Technology zones	Short-term	To be determined	To be determined	N/A
Regional bioscience councils	Short-term	\$250,000/ year each for two councils	0	All private
Image, marketing, and business development	Long-term	Redirect existing resources	0	N/A
Capacity to understand and address health policy issues	Long-term	\$3 million a year	0	From philanthropic and other sources
K-12 education	Long-term			
• Curriculum development			\$250–\$500,000	1:2
• Support for science teachers		\$1–\$2 million		
• Loan forgiveness programs		\$5–\$25 million		
Expanded internships and co-op programs	Long-term	\$200–\$500,000 logistics support leveraged with significant private support	0	1:3

Organization and Structure

State science and technology initiatives are most effective when they are executed on a bipartisan basis, with strong executive and legislative branch support, involvement, and cooperation. States such as Pennsylvania, New York, Georgia, Maine, Maryland, and North Carolina have been successful with their science and technology investments because their efforts have been broad based, they have mobilized private sector champions behind them, and their initiatives have become institutionalized into the state and regional fabric of both economic development and higher education.

Arizona's current structure and organization for science and technology reflects several factors:

- An historical but still vibrant state government focus on "clusters." In the biosciences, however, the result has been the creation of two organizations – one that primarily represents Tucson and one based in Phoenix that, while statewide in stated purpose, is more appropriately considered a Phoenix-focused group. Arizona has had a coordinating person in the

Department of Commerce, but the state's direct interest in the biosciences has been primarily ministerial and secretarial in nature.

- Science and technology issues have generally been adopted statewide by existing business groups and organizations reflecting varying interests, e.g., manufacturing, service sector, chambers of commerce, leadership groups.

This Bioscience Roadmap proposes a set of strategies and actions that involve many private and public sector organizations. This is not an attempt to redesign or restructure the state's science and technology apparatus since that was neither the mission nor the objective of this effort. It is an attempt to determine how these strategies can be effectively implemented, particularly the critical action items listed earlier in this section.

Directing this Bioscience Roadmap and serving as steward are both sensitive and critically important to the success of the entire set of strategies. Therefore, Battelle suggests that the most appropriate approach is to form the Arizona Bioscience Research Alliance (ABRA) to both coordinate efforts and, where necessary and appropriate, directly operate programs such as the Arizona Bioscience Research Enhancement Fund, the Bioscience Matching Challenge Program, and/or the Entrepreneurial Assistance Center. One or more of these programs might be more appropriately managed by a newly created nonprofit or for-profit (such as the Entrepreneurial Assistance Center, which also would co-manage the BioSeed Fund and the Technology Commercialization Prototype Development Fund).

It is Battelle's recommendation that ABRA should be legally organized as a private, nonprofit corporation with a majority of its board from industry. The board should include public and private members, such as the following:

- Governor's representative
- The Director of the Arizona Department of Commerce
- The Chairman of the Arizona Board of Regents
- One representative of each caucus of each House (4) of the Legislature
- One representative from each of the state's proposed two regional bioscience organizations
- Nine industry representatives, including medical device, drugs and pharmaceuticals, research and testing, agriculture, environment, health care, optics, imaging, and other sectors.

Except for industry representatives, other members of the board shall serve terms concurrent with the positions they hold. Legislative members will be appointed for the length of their legislative terms. Industry representatives will serve one-, two-, and three-year staggered terms among the nine, with three members in each initial grouping, and thereafter serve three-year terms. Such representatives may be reappointed without term limitations.

The roles and responsibilities of the Arizona Bioscience Research Alliance shall include the following:

- Selecting a CEO and other support staff as necessary. The Alliance will always operate with a small core staff, except where it directly operates programs.
- Working with all sectors to focus on implementing the Roadmap Alliance and primarily operating the Arizona Bioscience Research Enhancement Fund. The Alliance may assist in directing or operating other activities on an interim or permanent basis. Whereas, in the past,

playing the role of strategist, planner, and coordinator was argued as inconsistent with the role of direct operator, experience around the country suggests that such vehicles and organizations tend to be ineffectual without some direct operational role, with sufficient, impactive control of resources.

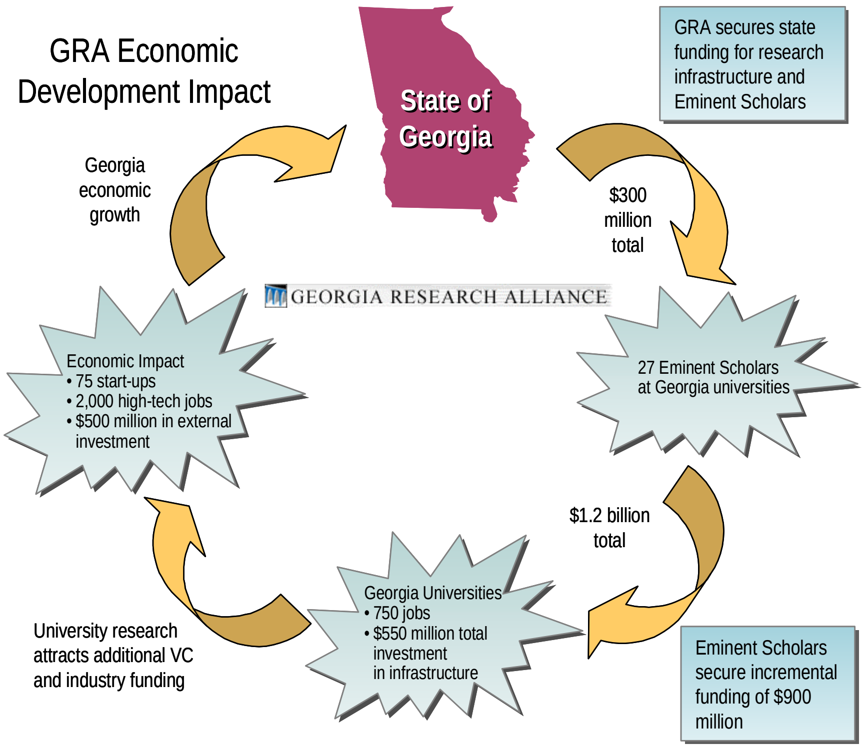
- Approving and funding centers, institutes, and accompanying facilities, core labs, recruitment packages, and related investments in centers, consortia, and institutes within the current Bioscience Roadmap list of near- and long-term technology platforms (as they are updated from time to time). Reviewing and monitoring progress of designated centers.
- Reviewing and making recommendations to the Governor and Legislature on the success of the Arizona Bioscience Research and Enhancement Fund and other programs operated by the Alliance, suggesting changes in statutory language, resource utilization, or other issues, as appropriate.
- Serving as a knowledge economy strategic policy group working with higher education policy organizations, as well as business groups and organizations, to further position business-higher education partnerships in Arizona.

The Arizona Bioscience Research Alliance also is expected to work closely with the Arizona Department of Commerce, the Arizona Board of Regents, and the state's three public research universities and their leadership to ensure that related science and technology programs are linked to its efforts. In addition, since many of the actions proposed in this Roadmap will need to be implemented at the local level, local government will have an important role in strategy implementation. This role will necessitate its participation and involvement in the Alliance as well.

The structure proposed for the Arizona Bioscience Research Alliance is similar to that of the Georgia Research Alliance (Figure 18). The GRA is a nonprofit organization that focuses on building a strong research base in that state's higher education system through endowed chairs, facilities, recruitment packages, matching funds, and related programs. Beginning in 1990, a consortium of Georgia's business leaders conceived and founded the GRA to leverage the state's research universities with the state's economic development. GRA has managed to leverage state funds many fold. Since 1992, the State of Georgia has invested more than $300 million and established endowments for 37 Eminent Scholar positions. GRA also invests in the physical infrastructure for conducting research and its commercialization. More than 40 research facilities and centers of research excellence have had their construction, renovation, modernization, expansion, or equipment needs supported by GRA investments.

The Arizona Bioscience Research Alliance will focus on both research excellence and technology commercialization around the core research areas and technology platforms described earlier in this report. Georgia had not given particular attention to technology commercialization until recent years. For the past decade, Georgia has emphasized the building of research capacity, resulting in its higher education being nationally competitive in life sciences, engineering, and other research areas.

Figure 18. Georgia Research Alliance Model



Battelle, for a number of reasons, including the need for a more flexible and agile organization, proposes a separate entity established outside of state government for Arizona. A separate board will make funding decisions based on merit easier and will provide for an organization with ties to government but with board terms overlapping those of elected officials. This will provide the continuity necessary for long-term bioscience investments. Most importantly, it will put Arizona industry in a majority role, ensuring that these efforts are industry relevant and market sensitive.

Arizona's bioscience delivery system will be composed of the following key components:

- The Arizona Bioscience Research Alliance
- Entrepreneurial Assistance Center, co-managing the BioSeed Fund and Prototype Development Fund
- Technology-led trade and civic organizations in each region, working together on statewide needs and issues
- Arizona's higher education anchors, including research universities, comprehensive universities, and community colleges.

Arizona cannot stand still and remain economically viable while other states make key investments in their future around the biosciences. The key to the success of this Roadmap is sound execution that requires talent, commitment, and perseverance. Strategies can be successful only if implementation is achieved.

Measures of Success and Accountability

The following measures are performance measure goals, with actual monitoring undertaken on an ongoing basis through the Arizona Bioscience Research Alliance to determine to what degree performance objectives are being accomplished. Key measures that could be used to monitor progress include the following:

- Increase in bioscience R&D funding to Arizona research institutions at a rate equal to or greater than the historical growth rate of the top 10 states over the next five years.
- An increase in NIH funding from $118 million to $214 million by 2007.
- Start-up and survival rates of Arizona bioscience firms exceeding the average rates for benchmark states as identified in this Roadmap.
- An increase in the concentration rate and thus degree of specialization relative to the nation in at least two industry segments (LQ >1.20) by 2007.
- Leveraging of federal and other dollars at least three times for every $1 in Arizona support.
- Dollars of bioscience venture investments to Arizona-based firms to total at least $100 million in 2007.
- Arizona university-related start-ups/revenue dollars to exceed the top quartile ratio of all U.S. universities by 2007.
- Implementation progress on the actions laid out in this Roadmap—at least 70 percent with substantial action after three years, and 90 percent within five years.

In addition to these outcome and impact measures, Arizona should update this Roadmap every three to five years to adjust to changing economic conditions.

Economic Impact Analysis

The Arizona Bioscience Roadmap lays out a list of strategic investments across the entire continuum of bioscience development, from basic research to firm formation and attraction. This multiyear investment program, stretching over at least a decade or more, will provide the types of investments at a sufficient scale to achieve a critical mass of research around key technology platforms and, ultimately, result in a critical mass of bioscience firms populating Arizona by 2012.

Battelle's economic impact analysis indicates that the investments recommended in this Roadmap can result in the following impacts:

Critical Mass of Research Support

- The State of Arizona can reach a level of NIH funding equal to the historical growth rates of the top 10 states in NIH funding by 2007, resulting in $274 million of annual federal NIH funding, compared with $115 million today, an increase of $159 million more a year. By 2012, this NIH funding level is projected to grow to $385 million in annual funding, an increase of $270 million annually.

- Funding support for research facilities, faculty recruitment, and instrumentation can be returned manyfold through increased ability to attract federal research funds to Arizona. It is projected that these facility and faculty investments will attract over three times their costs within the next 10 years. If these investments are not made in Arizona, these federal funds will be awarded elsewhere in the country.

Critical Mass of Businesses and Jobs

- Arizona's nonhospital biosciences industry employment can grow over the next decade from 9,100 jobs today to nearly 22,000 jobs or an additional 12,900 jobs by 2012. This includes over 10,000 jobs from the expansion of the existing bioscience firm employment base, with the remainder from new start-ups and relocations to the state. This critical mass of bioscience firms will have a multiplier effect on other business service and supplier sectors of the economy, accounting for an estimated 17,000 additional jobs in all sectors of Arizona's economy.
- Arizona's base of bioscience firms can grow by an additional 120 firms over the coming decade, composed of both start-ups and relocations.
- An additional 1,350 new research positions at the state's higher education institutions and other research centers can be created over the next decade.

Leveraged Investments

- Investments in the Bioscience Roadmap would require $140 million a year in private, philanthropic, and state investments over the coming decade, attracting an additional average outside investment to Arizona of $280 million per year.
- For specific investments in the Bioscience Roadmap designed to leverage other financial support, every $1 that Arizona's private and public sectors provide is estimated to leverage $6.26 in other investments.

Return on Investment

- Certain proposed actions in the Bioscience Roadmap should be considered traditional return-on-investment opportunities, such as the proposed Arizona BioSeed Fund and private-developer-financed, multitenant laboratory space. For such investment opportunities, returns can be significant. For example, venture capital investments have had a mean annual return of 57 percent between 1987 and 2000[40] and real estate investments have exceeded 8 to12 percent for bioscience space.

[40] John Cochrane, "The Risk and Return of Venture Capital," NBER Working Paper No. 8066, www.nber.org/digest/may01/w8066.html.

Conclusion

The Roadmap Alliance lays out a comprehensive action plan to position Arizona as a major southwestern state in the biosciences. Arizona can accomplish this plan by focusing its research efforts on key technology platforms, building collaboration across institutions and organizations, and concurrently focusing on both building the research enterprise and supporting the private and public technology commercialization vehicles that can turn research into quality medical practice and a critical mass of bioscience firms. Overall, this Roadmap proposes a bioscience agenda based on private sector market-driven needs, and recommends actions that are implemented around filling private sector gaps through private-public partnerships, led by industry.

Now is an opportune time for Arizona to initiate bold action to ensure long-term prosperity for its citizens through a comprehensive partnership of its private and public sector leadership to build Arizona's future in selective fields of the biosciences. In recent months, much public attention and momentum have resulted from Arizona's successful efforts to attract the Translational Genomics Research Institute (TGen) and the International Genomics Consortium (IGC). However, TGen and IGC are but one anchor of a much broader set of strategies and actions that will be necessary to position Arizona as a major southwest bioscience center over the coming decades. To address this issue, Arizona's leaders are seeking to develop strengths in those technology areas expected to lead future economic growth—chief among them is the bioscience sector.

Arizona must play "catch up" to other states in building a world-class research base, as well as translating this base into clinical care and treatment and commercialization of technology through a critical mass of bioscience-related firms. However, Arizona's current situation is not unique. Other states and regions once behind in the development of their bioscience sectors (including San Diego, California; Montgomery County, Maryland; Birmingham, Alabama; and Portland, Oregon) either have successfully positioned themselves as a leading bioscience region or are focusing their strategic investments to carve out a particular market niche for the future.

Arizona must approach its future in the biosciences by

- Further investing in and building Arizona's world-class research and clinical and product excellence around selective bioscience sectors established through interdisciplinary centers and consortia. The goal is to have Arizona's growth rate in NIH research funding comparable to that of the top 10 states in the nation by 2007.
- Putting in place mechanisms, programs, and incentives that encourage research to be turned into products, processes, and wealth generation for the state and its citizens. Vehicles must be in place to accelerate the ability to "mine" a growing research and development base for commercial and technological development.
- Mobilizing public and private leadership and increasing citizen knowledge and understanding of the biosciences and its impact on health and safety, teaching and research, and economic development (bed, bench, and classroom)

- Building "trees of talent" by encouraging scientific and technical talent to be developed and retained in the state.

The state's public and private leadership must focus on the following factors to turn this Roadmap into reality:

- ***Having patience and a long-term commitment to the biosciences.***
- ***Having identified champions in the private and public sectors for the biosciences.***
- ***Maintaining a strategic focus by research organizations on the technology platforms.***
- ***Initiating a strong public-private partnership in the implementation of each of the actions in the Roadmap.***
- ***Involving the public sector, at all levels, in these efforts (state, regional, and local governments).***
- ***Ensuring a continued willingness on the part of the state's research institutions to partner within and across institutions to build research stature and reputation in selective fields of the biosciences.***