Colorado's Place in the Sun: A Bioscience Future

# An Action Plan to Grow Colorado's Bioscience Cluster


Colorado Office of Innovation and Technology



Sponsored by:

Amgen, Inc.

Colorado Economic Development Commission

Colorado Institute of Technology

Denver Metro Chamber of Commerce

IBM Corporation, Life Sciences

State of Colorado, Governor's Office of Economic Development and International Trade

March 2003

Battelle Memorial Institute (Battelle) does not endorse or recommend particular companies, products, services, or technologies, nor does it endorse or recommend financial investments and/or the purchase or sale of securities. Battelle makes no warranty or guarantee, express or implied, including without limitation, warranties of fitness for a particular purpose or merchantability, for any report, service, data, or other information provided herein.

Copyright 2003 Battelle Memorial Institute. Use, duplication, or distribution of this document or any part thereof is prohibited without the written permission of Battelle Memorial Institute. Unauthorized use may violate the copyright laws and result in civil and/or criminal penalties.

## COLORADO'S PLACE IN THE SUN: A BIOSCIENCE FUTURE

# An Action Plan to Grow Colorado's Bioscience Cluster

**Colorado Office of Innovation and Technology**

**Support Provided by:**

**Amgen Inc.**

**Colorado Economic Development Commission**

**Colorado Institute of Technology**

**Denver Metro Chamber of Commerce**

**IBM Corporation, Life Sciences**

**State of Colorado, Governor's Office of Economic Development and International Trade**

**March 2003**

## TABLE OF CONTENTS

# Executive Summary

As one of the most dynamic and growth-oriented sectors of the economy, the biosciences offer tremendous opportunities for economic development. The biosciences represent a major slice of our economy, reaching into a significant and vast array of industries, from drugs, medical devices and clinical care in the human and animal fields to agricultural and plant sciences. The common factor across these industries is the application of biological knowledge and processes.

Today the biosciences sector is at the forefront of creativity and innovation. Following the successful completion of the Human Genome Project, a new era of innovation is being unlocked, creating new arenas of research and application from bioinformatics to proteomics, combinatorial biology and personalized medicine. At the same time, progress in microelectronics, robotics, biomaterials, and nanotechnology is establishing new avenues for advancements in medical devices, drug delivery, and surgical practices.

In 1999, Colorado created the Governor's Office of Innovation and Technology (OIT) whose mission is to make Colorado a world leader in the formation and implementation of technology During the last four months, OIT, assisted by a management team that included industry, university and government representatives and with support provided by Battelle Memorial Institute's Technology Partnership Practice, has assessed the current status of Colorado's bioscience sector and has sought input from leaders of the state's research institutions, researchers, entrepreneurs, CEOs of biosciences companies, economic development organizations, and other services providers to determine what needs to be done to ensure that Colorado is fully realizing the opportunities provided by the revolutionary changes occurring in the biosciences. This plan outlines an action agenda designed to make the biosciences a key driver of Colorado's economy. But why should Colorado seek to develop its bioscience sector? A brief look at the history of Colorado's economy suggests that Colorado needs to diversify its technology economy just as it has had to diversity its economy in the past.

## COLORADO'S ECONOMY

Colorado's economic history has been one of boom and bust. Statehood was in fact catalyzed by the economic boom generated by the discovery of gold. Although the discovery of gold was not long sustained, the mining industry continued to be the dominant sector through the end of the century. When the depression of 1893 and the repeal of the Sherman Silver Purchase Act abruptly ended the state's first boom, civic leaders recognized the need to diversify the economy, and turned to agriculture, manufacturing, tourism, and services. As a result, the economy grew steadily although more slowly through much of the first half of the twentieth century.

The next significant boom came when Colorado became home to numerous regional and national headquarters of oil and gas firms after World War II. However, during the 1980's oil bust when the price of crude oil dropped from $39 to $9 a barrel, the state sank into a severe recession. State government responded by creating the Colorado Advanced Technology Initiative (CATI),

funding the Economic Development Commission, adding a business development office, and developing several public sector infrastructure projects.

As the 1990s began, the Colorado economy began to recover and outperform the national economy. By the end of the decade, Colorado was again in a significant boom cycle. The state's population was consistently growing two and a half times faster than the national growth rate. In addition, between 1992 and 1998 Colorado had the fifth fastest growing gross state product in that nation, with an average 6.6 percent annual growth rate. Much of this new growth was spurred by information technology (hardware and software) companies. By 2000, Colorado placed first in the nation in the concentration of high technology workers.

However, the boom of the 1990s ended in bust at the turn of this century with the collapse of the dot.com phenomena and the significant downturn of the IT sector. The state has been affected by the same factors that caused the national downturn in the IT industry. However, since Colorado had a higher than average concentration in this sector, its economic impact has been more severe.

Just as civic leaders recognized at the turn of the last century that the state needed to diversify its industrial base beyond mining, so too must the leaders of this century seek to diversify in today's rapidly changing technology-based economy. While the IT industry can be expected to rebound once the national economy recovers, Colorado also needs to develop other technology sectors, most particularly biosciences, to sustain its future development, offering jobs and contributing to a healthy citizenry, too.

## WHY DEVELOP THE BIOSCIENCES IN COLORADO

The bioscience sector[1] is a rapidly growing, global industry characterized by scientific and technological innovation and discovery. It involves a collection of industries with a wide variety of applications ranging from life saving drugs to cleaner bio-engineered fuels, from new medical imaging devices to healthier foods, from mapping the human genome to safeguarding against bio-terrorism. There are a number of reasons for seeking to develop Colorado's bioscience sector.

***The bioscience sector offers the opportunity to create high wage, skilled jobs for Colorado residents, thereby creating wealth for Colorado citizens.***

Colorado wage information indicates that jobs created in the bioscience industry are among some of the highest paying jobs within the state. Table ES-1 presents annual average employee wages

**Table ES-1: Colorado Average Annual Employee Earnings**

| Colorado Average Annual Employee Earnings | |
|---|---|
| Industrial Machinery | $65,064 |
| **Research & Testing** | **64,331** |
| **Drugs & Pharmaceuticals** | **54,473** |
| **Medical Devices** | **47,018** |
| Aerospace | 46,505 |
| **Organic & Agricultural Chemicals** | **42,423** |
| Metals | 41,349 |
| Rubber & Plastics | 38,935 |
| **Entire private sector** | **37,553** |
| Construction | 36,967 |
| Motor Vehicles | 34,511 |
| Hospitals & Laboratories | 33,620 |

[1] In this report, the term "biosciences" refers to a relatively broad range of biological and life-sciences-related activity including drugs and pharmaceuticals, agricultural and organic chemicals, medical device and instrument manufacturing, and bioscience research and testing. The data on employment and establishments are taken from Dun & Bradstreet's *MarketPlace* survey.

received in 2000. All four subsectors of the bioscience sector exceed average annual earnings for the entire private sector. Research and testing (biotechnology) offers the highest annual wage of all the bioscience subsectors. Research and testing is also the fastest growing subsector in the state, indicating a significant opportunity for the state to foster wealth creation by encouraging the growth of this fast paced subsector. Medical devices is another high paying subsector in the state that possesses a significant presence in terms of its employment size and significance.

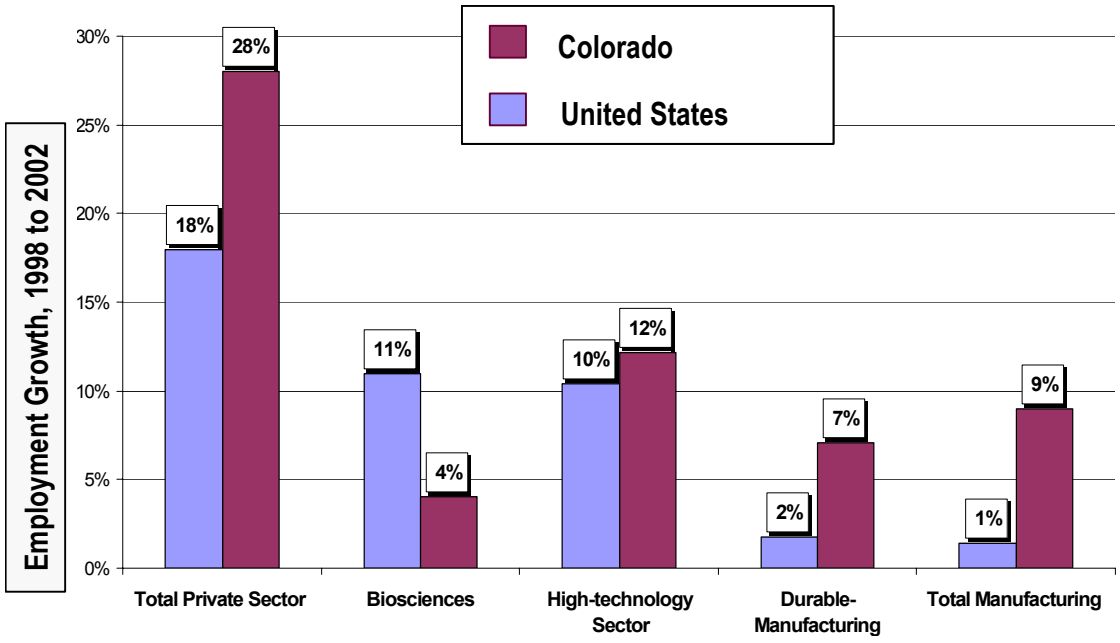
***The bioscience sector offers a broad range of jobs requiring a variety of skills and education.*** The broad range of occupations that biosciences support is often not recognized. The biosciences offer abundant employment opportunities over the entire range of education and experience levels, from 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—accounting for 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.[2]

***The biosciences is a high growth sector.*** The bioscience sector of the economy is large, fast growing, diverse, and crosscutting. It involves 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. Moreover, the recent surge of advances in the field suggests great potential for rapid growth of new bioscience firms.

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

Nationally the bioscience industry has experienced employment growth that has surpassed increases in other sectors of the economy. Over the past four years, bioscience industries[3] have grown by 11 percent, adding 120,679 jobs nationally. During the same time period, the high-technology sector, which includes the biosciences, grew 12 percent nationally and manufacturing grew only one percent. (See Figure ES-1.)

**Figure ES-1: Employment Growth 1998 – 2002**




Colorado's high technology sector grew even faster than that of the nation growing by 12 percent between 1998 and 2002. While the bioscience sector in Colorado only grew by four percent in employment during this time period in comparison to a national increase in employment of 11 percent, the research and testing (biotechnology) component of the biosciences grew 95 percent in Colorado in comparison to a 35 percent growth rate nationally. Colorado has the opportunity to capture a greater share of the nation's growth in the biosciences, a sector that is expected to continue to experience significant growth.

The bioscience sector can bring stability to Colorado's economy. As an economic driver, the diversity of the bioscience sector ensures relative stability. Because demand for medical-related and food products remains fairly constant year after year, development of the biosciences provides insulation against the ups and downs of business cycles.

### *The biosciences is a renewable industry sector, i.e., the industry is dynamic.*

Talent and companies churn and firms continue to develop products and applications for technologies on an ongoing basis. Studies of the evolution of existing bioscience centers, such as San Diego and Maryland, show that as bioscience companies succeed they tend to spawn new companies. In some cases, firms will be acquired and the original founders will move on to start other companies. In other cases, employees will leave successful companies to start ventures of

[3] Bioscience industry includes drugs and pharmaceutical, organic and agricultural chemicals, medical devices and instruments, and research and testing.

their own. In San Diego, more than 45 firms trace their lineage to a single bioscience company, Hybritech.[4] A recent study of founders of Maryland bioscience and medical instrument companies found that "the growing maturity of the bioscience/biomedical sector in Maryland has allowed it to begin to perpetuate itself through spin-offs of subsidiaries/affiliated companies, spin-outs of employees eager to run their own businesses, and 'serial entrepreneurship' by several individuals who have built and sold a series of companies."[5] Colorado not only has a base of emerging bioscience companies with the potential to generate additional firms and products as they mature but established companies such as Amgen, that are already generating additional activity in the biosciences.

***The bioscience sector can contribute to the growth of Colorado's other technology sectors, such as information technology, photonics, and advanced manufacturing.*** The biosciences is unique in its inherent diversity, combining activity and expertise from biology, agriculture, medical sciences, animal sciences, public health, organic chemistry, engineering, and computer science, among other fields. This diversity places the bioscience sector at the center of the technology economy, serving as a focal point for the continuing convergence of technologies. The bioscience industry is increasingly interacting with other technology sectors—such as electronics, information technology, optics, and agriculture. Applications and spin-offs from the biosciences may indeed help boost other Colorado technology-based industries, such as advanced manufacturing and information technologies.

**Examples of Colorado companies linking biosciences and photonics sectors:**

- Hamamatsu: develops and manufactures equipment for biomedical imaging.
- PhotoSense, LLC: a development stage company bringing innovative non-invasive optical sensing technology to medical, industrial and environmental applications.
- Hach Company: provides advanced analytical systems and technical support for water quality testing, with solutions for lab, process, and field. The company uses advance optical analytical instruments.

***Colorado has a significant foundation on which to build a bioscience cluster.*** Colorado has a significant bioscience research base at the state's institutions of higher education and other major non-state institutions that is growing rapidly. Colorado's total bioscience research funding reported by the NSF grew 31percent from FY 1996 to FY 2000, compared to 27 percent for the nation. In the past five years, funding for the University of Colorado Health Science Center (UCHSC) has nearly doubled from $150.5 million to $249.6 million, with an average growth of 14.2 percent per year during this five year period. For the same period, Colorado State University's (CSU) research funding in its Colleges of Veterinary Medicine, Agricultural Sciences, and Natural Sciences Resources grew from $67.8 million to $109.5 million, representing an average increase of 12.3 percent per year.

[4] Innovation Associates. *Developing High-Technology Communities: San Diego*. Washington, D.C.: Office of Advocacy, U.S. Small Business Administration, March 2000.
[5] Marsha R. B. Schachtel and Scott R. Heacock. *Founders of Maryland Bioscience and Medical Instrument Companies*. Maryland Department of Business and Economic Development and Maryland Technology Development Corporation, August 2002.

Colorado has a growing base of bioscience companies. In 2002, the state had employment of 17,681 across 604 establishments in the biosciences. Between 1995 and 2002, the number of bioscience establishments in Colorado grew slightly faster than the U.S., increasing by 35 percent compared to 29 percent at the national level. During this same time period, employment in Colorado's bioscience sector increased by four percent.

**Table ES-2: Colorado Bioscience Sector**

| Colorado Bioscience Sector | |
|---|---|
| • **Establishments** | **604** |
| *Percent Change '95–'02* | *34.5%* |
| • **Employment** | **17,681** |
| *Percent Change '95–'02* | *4.3%* |
| • **Percent of private sector employment** | **0.76%** |
| *U.S. percent share of private sector employment* | *0.88%* |

Colorado has a strong record of venture capital investment that will enable bioscience companies to expand and grow in Colorado. Lastly, Colorado has educational institutions that can produce graduates with the skills and education needed to meet the diverse needs of the bioscience industry.

### *Developing the bioscience R&D base of Colorado's medical research institutions will lead to high quality health care for Colorado's citizens.*

Bioscience discoveries are leading to new possibilities for the diagnosis and treatment of a wide range of diseases. Breakthroughs in genomics will soon allow scientists to tailor treatments to specific diseases in specific individuals. It is estimated that within 20 years designer drugs will target specific genetic variations in diseases. Colorado has the opportunity to create an interrelated system of bioscience research, teaching and patient care that builds on its existing hospitals and research institutions to provide state-of-the art health care to its citizenry.

## A Vision for Colorado's Biosciences: Colorado's Place in the Sun

Colorado's public, private and academic communities believe that by being active and strategic the biosciences can become a significant contributor to the state's future economy. Our vision for what Colorado will look like ten years from now is as follows:

> *Colorado is the preeminent life science center for the Mountain Region, serving health care needs throughout the nation and around the world by virtue of its excellent research, education, and clinical institutions. Colorado has a vibrant cluster of bioscience companies that are developing technological solutions to address health care, environmental, agricultural and veterinary, and national security needs.*

## REALIZING COLORADO'S BIOSCIENCE VISION: WHAT IT WILL TAKE

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 base shows that they share a number of characteristics. They include

**Key Success Factors**

- Engaged research organizations 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 research organizations with active leadership across research, technology commercialization, and industry partnerships.*** An outstanding set of research organizations 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. Of particular importance are programs to assure development of world-class research capability; willingness to engage with industry; an institutional commitment to a role in regional economic development; and presence of a technology commercialization infrastructure.
- ***Intensive networking across sectors and with industry.*** Success in building technology clusters requires extensive collaboration among individuals and institutions spanning a range of academic disciplines and institutions, diverse industrial sectors, and the diverse and somewhat incompatible cultures of industry, academia, and state and local government. In a few leading communities like Silicon Valley, this networking has occurred naturally. However, in the vast majority of American regions, mechanisms that encourage and support networking and collaboration need to be created. The distinguishing characteristics of successful networking efforts in the biosciences are:
    - They are driven and led by industry, although government and academia may strongly participate and from time to time assume leadership roles;
    - They are either focused on bioscience exclusively or provide for a "special interest group" that can focus on this subsector of technology; and,
    - Their industry leadership is from technology generators and users, not solely from providers of business services.
- ***Available indigenous 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 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. There must be private investment capital available to support the development of a pipeline

of bioscience start-up companies as well as established venture funding available to companies as they move into manufacturing products for the marketplace.

- ***Discretionary federal or other R&D funding support.*** To cultivate R&D excellence in particular niches that may lead to commercial relationships and start-ups, it is vitally important for regions to leverage substantial, ongoing, external, discretionary (non-formula) R&D 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). Securing federal centers and institutes as research anchors as well as discretionary Federal R&D funding are both important.
- ***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.
- ***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.
- ***Stable and supportive business, tax, and regulatory policies.*** Bioscience companies need a regulatory climate and environment that encourages and supports 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.
- ***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, San Diego and Maryland emerged as major bioscience centers 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—in short, a marathon team effort, not a single sprint runner.

Table ES-3 provides a "gap analysis" comparing Colorado on each of these lessons with best practice bioscience states and regions on the key success factors.

**Table ES-3: Comparison of Colorado to Best Practice Bioscience Regions**

| Factors of Success | Best Practice States/Regions | Colorado Situation |
|---|---|---|
| **Engaged Universities with Active Leadership** | ✓ Universities are engaged in economic development and committed to technology transfer.<br>✓ Have created vehicles for technology commercialization. | ✓ Higher education and bioscience industry have a weak record of collaboration.<br>✓ Improvements have been made in technology transfer and commercial-ization, but time is needed for technology transfer improvements to mature and greater investment in technology commercialization is needed. |
| **Intensive Networking** | ✓ Active technology intermediary organizations provide a focal point for the state's biotechnology efforts.<br>✓ 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. | ✓ Colorado has several organizations that foster networking including the Colorado Biotechnology Assn., the Colorado Medical Device Assn., and the Colorado Alliance for Bioengineering. The Colorado Bioscience Park Aurora sponsors Bio Breakfasts and Bio West events that have been successful in showcasing Colorado bioscience companies. |
| **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.<br>✓ Active informal angel networks investing in the biosciences.<br>✓ Investors include private, philanthropic, and public entities. | ✓ Colorado has several local venture capital companies which invest in bioscience companies, including Sequel Ventures.<br>✓ A gap in pre-seed/seed funding stage exists.<br>✓ Limited angel networks are investing in the biosciences.<br>✓ Later stage funding will be necessary in future years as a critical mass of bioscience firms matures. |
| **Discretionary R&D Funding** | ✓ Every major technology region in the U.S. has received significant federal discretionary funding.<br>✓ One or more federally designated centers exist that serve as anchors for the state or region's bioscience base. | ✓ Colorado's universities have been very successful in competing for federal R&D dollars but less successful in obtaining industry R&D support.<br>✓ CSU is leading a regional effort to secure funding for a regional center of excellence in bioterrorism and emerging infectious diseases.<br>✓ Existing DOD, DOE, Commerce, HHS, and USDA federal labs and facilities exist on which to build relationships. |
| **Talent Pool** | ✓ Talent increasingly provides the discriminating variable for states and regions to build comparative advantage.<br>✓ 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. | ✓ Colorado has a highly educated population and available skilled workforce.<br>✓ Colorado attracts educated workers to relocate to the state.<br>✓ Colorado has not yet achieved a critical mass of companies which may discourage managers with bioscience experience to relocate to Colorado.<br>✓ Colorado's education and training providers produce high quality talent. |

**Table ES-3: Comparison of Colorado to Best Practice States and Regions on Key Success Factors (continued)**

| Factors of Success | Best Practice States/Regions | Colorado Situation |
|---|---|---|
| **Specialized Facilities and Equipment** | ✓ Leading bioscience regions have private markets that provide facilities offering space for bioscience companies.<br>✓ Specialized bioscience incubators and research parks are common.<br>✓ Access to specialized facilities and equipment, such as core labs, and animal facilities, is readily available. | ✓ Colorado Bioscience Park Aurora is the first university affiliated park focused exclusively on the biosciences in the Western U.S.<br>✓ Colorado has other technology parks, including CSU's Centre for Advanced Technology and Foothills Campus that can accommodate bioscience companies.<br>✓ Colorado has a good supply of buildings that can be adapted for use by bioscience companies.<br>✓ BSL-3 facility and Animal Cancer Center at CSU. |
| **Supportive Business Climate** | ✓ Incentives to encourage growth of technology-driven firms through modernized economic development tool kit.<br>✓ Tax structures generally leveled to treat technology-driven and manufacturing firms evenly.<br>✓ Established brand name/image around technology themes. | ✓ Colorado has a favorable business climate with stable tax and regulatory policies.<br>✓ Colorado has few economic development assistance programs/tools to attract, retain, and grow bioscience firms.<br>✓ Colorado perceives itself as lacking a national presence in the biosciences. While this may not be true, a brand/image is needed. |
| **Patience and Long-term Perspective** | ✓ Building a critical mass of bioscience firms takes many years or even decades.<br>✓ 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. | ✓ Colorado has been successful in growing the state's technology economy, particularly in IT.<br>✓ Colorado does not have a history of long-term, sustained and continuous state investment in technology development. |

To build Colorado's bioscience future will require an alliance of business, higher education and government with each playing appropriate synergistic roles. It will require:

- **Connections.** Colorado's academic, bioscience industry, and public sectors do not have a strong history of collaboration. In part due to the nature of the state's historic strengths in the medical devices industry, which at the time did not partner extensively with research organizations, industry and higher education have not "connected." Another contributing factor is the relative success of Colorado's higher education institutions in successfully securing federal funds. Relationships are not strong and neither industry nor academe is networked formally or informally. This plan identifies concrete ways to build these relationships.
- **Collaboration across organizations and sectors, and between companies.** Building sustained relationships and collaboration occur in many ways, whether it be sponsored research, education and training, or simply technical assistance and problem solving support. Like two ships in the night passing unseen, business and higher education in Colorado fail to take maximum advantage of each other's assets, needs, and opportunities that can help build both research excellence and establish more competitive industries. Many of the specific actions in this plan will require increased collaboration for their success.
- **Champions from both the public and private sectors who will commit to working to build the biosciences over the long-term.** CEO-level bioscience executives have not emerged historically to lead efforts to build Colorado's bioscience industry. Public, academic, and industry leaders have been focused on addressing technology infrastructure without direct attention to how this infrastructure may interact with the other sectors. This is not necessarily bad, but the sum would be greater than the parts if the three sectors would interact and develop a more cohesive approach. Also, Colorado's early success in communications and computing resulted in less attention to bioscience opportunities by the public sector. This overall plan, driven by industry-led groups and organizations, will require champions in the private, public, and academic sectors.
- **Commitment and continuous dedication to quality and long-term investment of resources.** Building technology-driven economies around biosciences takes long term commitment. Success needs to be measured over many years as the bioscience business model is not one (due to regulatory approvals and clinical trials) that results in quick introduction of new products although the time period varies across testing and diagnostics to drugs and treatment interventions. Colorado must not only embrace biosciences for today but for many tomorrows as well. This plan lays out a program for private and public action that will be accomplished over the coming five years. The results of these actions will be seen over the next decade and more.

## OPPORTUNITIES FOR COLORADO

### *Where Colorado Stands Today*

*Colorado has a strong medical device industry employing more than 11,000 people and accounting for 68 percent of total bioscience employment in the state.* The medical device sector is the only bioscience subsector in which Colorado has a specialization greater than the nation. This sector is 52 percent more concentrated in Colorado than nationally. However, Colorado's medical device sector experienced a five percent decline in employment between 1998 and 2002 at the same time that this industry grew two percent nationally.

*Colorado's research and testing (biotechnology) industry has experienced astonishing growth, nearly doubling in employment from 1998 until 2002.* In addition to outpacing all other Colorado bioscience subsectors, growth in research and testing, which experienced a 95 percent growth in employment between 1998 and 2002, is well above the national growth rate of 34 percent during the same time period. The large employment increase in the state's research and testing subsector has helped this segment to significantly increase its share of total bioscience employment. The effect of such rapid growth has led to an increasing level of employment concentration in the research and testing subsector. In 1998, Colorado research and testing held a location quotient of 0.66[6]. The subsector's current location quotient is 88 percent of the national average. *This increasing location quotient is highly significant when considered in the context of a state that has experienced employment growth across the entire economy at a rate above the national average.*

**Key Facts: Colorado Bioscience Subsectors**

- Medical devices, the largest subsector, employs 11,973 and accounts for 68% of Colorado bioscience employment.
- Medical devices is the most specialized subsector with a highly significant LQ of 1.52.
- Employment in research and testing (biotechnology), the fastest growing subsector in Colorado, increased by 95% between 1998 and 2002.
- Research and testing is becoming a specialization, now accounting for 13% of the bioscience sector compared to 7% four years ago.
- Drugs and pharmaceuticals, the second largest subsector, employs 2,782 and grew by 3% in employment.
- Organic and agricultural chemicals, the smallest and least regionally specialized subsector, employs only 576.

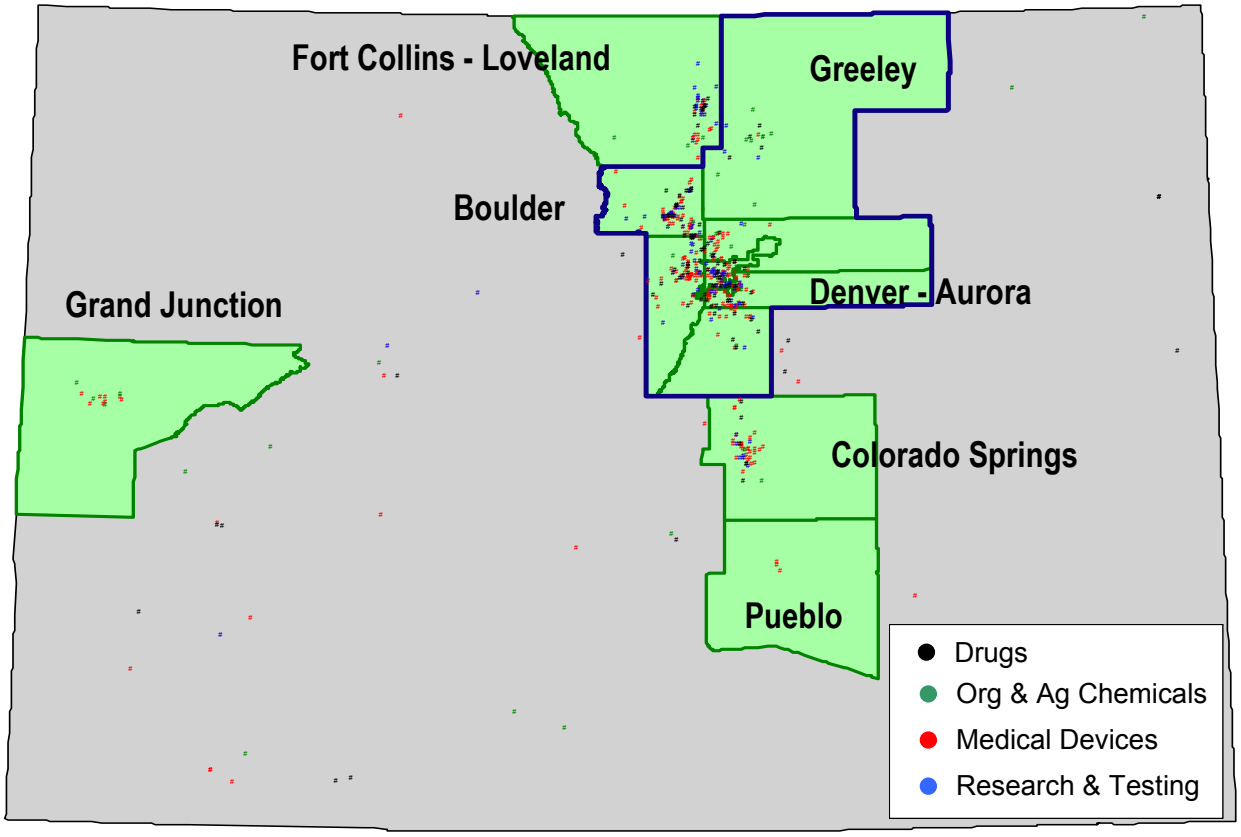
*Colorado has a diverse bioscience research base.* An examination of the fields of research within the biosciences in which Colorado research institutions have strengths reveals that there is significant institutional depth, particularly within the University of Colorado, Colorado State University and National Jewish Medical and Research Center, in a broad range of bioscience, biomedical and related disciplines. While Colorado has clear strengths in clinical human medicine, there also exists a substantial base of expertise in basic biological sciences, animal sciences, and plant and agricultural biosciences.

*Colorado's bioscience industry cluster is geographically concentrated.* Colorado's bioscience industry is predominantly clustered within the Greater Denver region. (See Figure ES-2.) Three of the Colorado

[6] Location quotients are a common measure of the concentration of a particular industry or industry sector in a region relative to a reference area. A location quotient greater than 1.0 indicates that the region is relatively concentrated in the particular industry. In this report, location quotients are used to report state industry concentrations relative to the United States.

metro areas that make up the Denver (includes Aurora)-Boulder-Greeley (includes Fort Collins-Loveland) Consolidated Metropolitan Statistical Area (CMSA) account for 80 percent of the state's bioscience employment and 73 percent of establishments. This clustering of companies offers an opportunity for Colorado to create a critical mass of bioscience companies by networking existing firms and providing an infrastructure to support their growth and development. Biosciences firms tend to geographically concentrate around academic health centers and research universities and Colorado's concentration provides a basis for further building a critical mass of firms.

**Figure ES-2: Geographic Distribution of Colorado's Bioscience Establishments**



## Colorado's Competitive Advantages

Colorado is not alone in seeking to grow its bioscience industry cluster. State and regions across the country are focusing resources on creating an environment that will encourage and facilitate the growth of their bioscience sectors. Colorado should build on its comparative advantages as the state seeks to grow the biosciences. These include:

*A highly educated population and available skilled workforce.* Colorado has one of the most highly educated populations among the 50 states. In 2000, 11.25 percent of Colorado's population aged 25 and older held graduate or professional degrees as compared to nine percent nationally. Colorado ranks first among the fifty states in the percentage of the population aged 25 and older that hold a Bachelor's degree or higher (34.6 percent). Colorado also has a base of science and engineering workers ranking second in the nation in the percentage of scientists and engineers in the workforce (1999).

*Dynamic entrepreneurial economy.* Coloradoans support risk taking and embrace new opportunities. Evidence of Colorado's strong entrepreneurial culture is found in the fact that Colorado 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*, Colorado ranked fourth 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. This dynamism ranking was comprised 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, Colorado ranked thirteenth in the nation in 2002.
- "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. Colorado ranked sixth in 2002.
- The number of initial public offerings (IPOs), a weighted measure of the value and number of initial public stock offerings of companies as a share of gross state product. In this category, Colorado ranked fourth in the nation in 2002.

In a study prepared by the Milken Institute for the California Technology, Trade and Commerce Agency's Division of Science, Technology and Innovation, Colorado ranked second after Massachusetts as the best positioned state to succeed in the technology-led information age.

*Attractive Life Style and Environment.* Colorado offers recreational opportunities and other amenities that offer a quality of life that many people, particularly highly educated, skilled technical workers, find attractive. While quality of life is a subjective factor, it is clear that Colorado's geography, climate, recreational and cultural amenities serve to draw people to the state. Between 1995 and 2000, the state's population grew by thirteen percent, much faster that the national rate of six percent. Colorado ranks third in net migration after Nevada and Arizona.

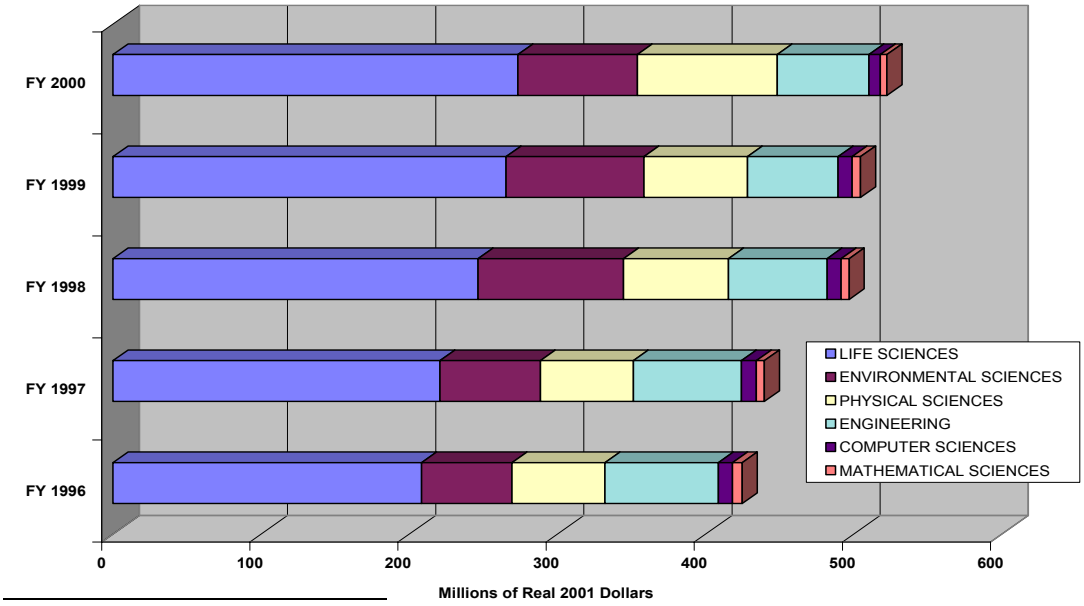
Surveys conducted on behalf of the Colorado Office of Economic Development found that Denver is highly rated among young professionals as a place to work and as a relocation site.

Anecdotal evidence indicates that graduates of Colorado's institutions of higher education tend to want to remain in the state, in some cases taking positions for which they are overqualified in order to remain. A study conducted for the National Science Foundation, which examined interstate migration of recent science and engineering graduates, found that 57 to 66 percent of students that had received degrees in Colorado were working in the state after graduation. In addition, Colorado ranked in the top quartile of states in the degree to which the state is a net importer of science and engineering graduates.[7]

*Attractive business climate.* Overall, the business climate in Colorado is favorable with a stable tax and regulatory environment. Colorado has achieved an A rating on key measures of business climate during the last seven years, the only state in the country to achieve this ranking, as measured by the Corporation for Enterprise Development that ranks states in term of economic performance, business vitality and development capacity.[8]

*Research institutions with strengths in selected bioscience areas.* Colorado is a major source of university based scientific research—bringing substantial funding into the state—and outpacing the state's overall ranking in population. Based on research funding data compiled by the NSF, Colorado's university research base in science fields totaled $559.7 million in FY 2000. This level of funding ranked Colorado 18th among the 50 states and the District of Columbia compared to its population rank of 24th in the nation. Bioscience research, which accounts for a substantial $273 million in total university research in Colorado, grew 31 percent from FY1996 to FY2000, compared to 27 percent for the nation.

**Figure ES-3: Academic R&D Spending in 11 Colorado Institutions, FY 1996–2000**




[7] Louis Tornatzky, Ph.D., Denis Gray, Ph.D.,/Stephanie Tarant, and Julie Howe. *Where Have All the Student Gone: Interstate Migration of Recent Science and Engineering Graduates*. Southern Technology Council, February 1998.

[8] Corporation for Enterprise Development. *Development Report Card of the States 2002*. Washington D.C., December 2002.

Colorado's university-based bioscience research is predominantly centered on the University of Colorado and Colorado State University,[9] both designated by the Carnegie Foundation as being in the highest level research classification group of "Doctoral/Research Universities – Extensive." Within these institutions, there are a number of individual departments that stand out within the NIH rankings data, including:

| Institution | Department | NIH Rank |
|---|---|---|
| | | Among medical schools |
| **UC Health Sciences Center** | Pediatrics | 3rd |
| | Biology | 7th |
| | Pharmacology | 7th |
| | Pharmacy | 11th |
| | Psychiatry | 12th |
| | Medicine | 14th |
| | | Among universities |
| **University of Colorado at Boulder** | Psychology | 10th |
| | Chemistry | 13th |
| | Genetics | 18th |
| **Colorado State University** | Veterinary Medicine | 3rd |

Source: NIH 2001 Extramural Awards to Medical School Departments, NIH 2001 Extramural Awards.

Colorado is also home to National Jewish Medical and Research Center, a private non-profit biomedical research institution. National Jewish ranked thirteenth among independent hospitals for NIH-funded biomedical research with a total of $26.7 million in NIH funding.

There are at least four federal laboratories with operations in Colorado: the National Oceanographic and Atmospheric Administration (NOAA) Environmental Technology Laboratory and the National Institute of Standards and Technology laboratory both located in Boulder, the National Renewable Energy Laboratory in Golden, and the Centers for Disease Control and Prevention (CDC) lab in Fort Collins. Other Colorado institutions that contribute to the state's bioscience base include Children's Hospital-Denver, the VA Medical Center-Denver, USDA and other related laboratories at the NRRC in Fort Collins.

***Strong Bioscience Infrastructure.*** Colorado has developed research parks and facilities that can support bioscience companies at each stage of the business life cycle, from early stage start-up to established companies with manufacturing operations. The **Colorado Bioscience Park Aurora** is a 160 acre research park located adjacent to the new UCHSC/UCH campus at Fitzsimons. Formally affiliated with CU, the Bioscience Park is the first of its kind west of the Mississippi. The first research park building, the Bioscience Park Center, opened in October 2000. The Bioscience Park Center houses the Park's administrative offices and provides incubator space to start-up bioscience companies as well as built to suit space for expansion stage companies. The building currently houses 18 start-up bioscience companies and three academic groups. Companies locating in the Park will have access to scientific support services and

[9] Other institutions of higher learning, such as the Colorado School of Mines, are also engaged in bioscience research, but at significantly lower levels of research volume versus the University of Colorado and Colorado State University.

facilities and the opportunity to enter into collaborative relationships with faculty and researchers at the UCHSC/UCH campus.

The Colorado State University Research Foundation, in conjunction with Everitt Enterprise of Fort Collins, has developed a multi-use technology park, known as the **Centre for Advanced Technology,** located directly south of the main campus of Colorado State University. The park currently houses and is expected to attract additional companies that wish to have a collaborative relationship with CSU. The Centre is home to the Natural Resources Research Center (NRRC) which is a campus of five buildings that house between 800 and 1000 federal employees. Companies housed at the Center include Atrix Laboratories, Inc. and Summit Plant Laboratories. **The University of Colorado Research Park** is located in Boulder and seeks to attract tenants desiring a collaborative relationship with the university. The **CSU Foothills Campus** is currently in the early stages of development and also offers a new venue for bioscience industry.

Colorado has several incubators that provide support for start-up technology companies including bioscience companies, such as CTEK, CVC (Colorado Ventures Center), Colorado Springs Technology Incubator, and the Ft. Collins Virtual Incubator. Each of these incubators provides support to technology entrepreneurs and start-up companies. CTEK has some space available to house companies but their main focus is providing mentoring and advice to client companies. Colorado also has an inventory of existing buildings that can readily be converted for use by bioscience companies.

***Quality manufacturing companies that have mass customization capabilities.*** One of the advantages Colorado has over even established bioscience areas is the ability to support the cluster at all stages of development from research and development through manufacturing and sales. Leading bioscience centers such as Boston and San Francisco are often not cost competitive for manufacturing. In Massachusetts, for example, only about 10 percent of the state's biotechnology companies are currently involved in manufacturing and of those, more than half do their manufacturing out of state.[10]

Colorado has a strong technology-based manufacturing sector. Colorado has more than 6,000 manufacturing companies with more than 205,000 Colorado employees. These firms produce a diverse mix of manufacturing products including high technology instruments, machinery, computer equipment, aerospace equipment, medical devices and pharmaceuticals. Colorado's strength in manufacturing means that the state will be able to capture the downstream, value added jobs that will be created by bioscience companies over the long run.

## Comparative Disadvantages

While Colorado is in a strong position to compete with other regions in developing its bioscience base, there are several areas in which Colorado is not as competitive as other regions with established or emerging biosciences bases. These include:

- ***Colorado's bioscience industry base is at an early stage of development***. Colorado has a rapidly growing research and testing (biotechnology) sector, with many small companies that have yet to introduce products in the market. Likewise drug and pharmaceutical establishments in Colorado employ an average of only 24 workers whereas nationally the average drug and pharmaceutical establishment employs 72 workers. These factors suggest

[10] The Boston Consulting Group and the Massachusetts Biotechnology Council, *MassBiotech 2010*, 2002.

that Colorado's bioscience sector has not yet reached the maturity of other leading bioscience centers. There is reason to believe however, that Colorado's drugs and pharmaceuticals sector will grow as more of Colorado's biotechnology research and testing firms mature.

- ***Higher education and bioscience industry have a weak record of connectivity and collaboration.*** In 2000, of a total R&D budget of $353.5 million at the University of Colorado system, only 2.6 percent came from industry. At Colorado State University, 4.3 percent of its 2000 R&D funding came from industry. Nationally, 7.2 percent of total university R&D funding at universities came from industry in 2000. [11] The lower percentage of funds coming from industry going to CU and CSU is due in part to the universities very successful track record in attracting federal R&D dollars. The one Colorado university with a significant percentage of its R&D funding coming from industry, albeit with a much smaller research budget of $21.8 million, is the Colorado School of Mines with 36.1 percent of its R&D funding coming from industry.
- ***Industries and universities in Colorado are not capturing the full potential commercialization of research findings***. Major improvements and changes are underway by the University of Colorado System and efforts continue at CSU and CSM to improve the management and transfer of intellectual property. Meanwhile, additional ways to move research toward commercialization, reduce to practice research findings, access capital, and provide mentoring by serial bioscience entrepreneurial managers will be needed to move university research findings into commercial products. The birth of new bioscience enterprises has remained strong in Colorado at the same time there has been an ongoing death of firms. As a result, Colorado has failed to build a critical mass as quickly as might be expected given its entrepreneurial culture and the size of its private venture capital base.
- ***Lack of strong public sector initiatives in support of the bioscience industry.*** While Colorado has undertaken a number of initiatives in the communications and information technology sectors in recent years, there has been less focus on biosciences with the notable exception of the new development at Fitzsimons and the Centre for Advanced Technology and regional biocontainment lab facility at CSU.
- ***Lack of perceived national presence***. Representatives of Colorado's bioscience sector indicated in interviews that a disadvantage of Colorado as a location for bioscience companies is the fact that the state does not have a national image as a center of the biosciences. Yet many reports in the media often cite Colorado as an emerging bioscience region. There appears to be a need to brand Colorado in the biosciences and to increase efforts to market Colorado's bioscience assets.

[11] Source: National Science Foundation/Division of Research Science Statistics, Survey of Research and Development Expenditures at Universities and Colleges.
[13] http://www.uchsc.edu/fitzsimons/

## COLORADO'S BIOSCIENCES FUTURE: LEVERAGING COLORADO'S UNIQUE ASSETS

Colorado should build its bioscience base by focusing on its unique assets and capabilities. These include first and foremost its entrepreneurial culture and its strong base of research institutions. It is recommended that Colorado grow the biosciences by:

- Nurturing home grown businesses;
- Creating excellence in selected bioscience research areas; and,
- Addressing the complexity of the research and industry enterprise through cooperative endeavors.

### Build Our Own

Colorado has a history of strong entrepreneurial development, ranking second among the fifty states in terms of new business start-ups in 2000. Colorado's bioscience sector consists primarily of small companies that have been started in Colorado. In 2000, Colorado's research and testing (biotechnology) companies had an average of 17 employees while the state's drugs and pharmaceutical companies had an average of 24 employees. Colorado has a rapidly growing base of research and testing (biotechnology) companies that, as they mature, will lead to growth in the state's drug and pharmaceuticals sector.

Colorado can foster the creation and growth of new start-up companies by providing support for entrepreneurs and emerging bioscience companies, ensuring the availability of venture capital in all stages of a company's life cycle and improving the commercialization of university inventions.

### Create Research Excellence in Selected Bioscience Areas

Colorado's bioscience research base is very diverse. An examination of publications data shows that UCHSC and CU-Denver published more than 100 papers in each of 25 different bioscience fields between 1997 and 2001. Similarly, the University of Colorado in Boulder and Colorado Springs published more than 100 papers in 19 different bioscience fields during the same time period. Colorado State University published more than 100 papers in six additional fields of the biosciences. Over the last three years, investigators at National Jewish and Medical Research Center have published hundreds of scientific articles in the areas of immunology, respiratory medicine and allergy. A tighter focus on selected niches will be needed if Colorado is to develop concentrated strengths to catch up with leading bioscience regions.

Based on a consideration of not only Colorado's research strengths but also where that research intersects with the state's industry base, competitive advantages and market opportunities, the following areas are identified as having near-term potential for development in Colorado:

***Pharmaceutical Biotechnology*** – This focus area would build on Colorado's considerable resources in basic biological sciences and expertise in specific fields of medicine and take advantage of the University of Colorado's Center for Pharmaceutical Biotechnology and Colorado State University's Bioprocessing Center. It would also support Colorado's existing base of companies involved with drug development and drug delivery systems.

***Medical Devices and Bioengineering*** – Colorado is already home to a concentration of medical device companies and the state's research institutions conduct significant research in bioengineering. The CU College of Engineering estimates that the College conducts $6 million in bioengineering research annually. CSU and CSM also have research strengths in particular areas of bioengineering. This focus area would build on Colorado's competencies in biomaterials, BioMEMS/nano-technology.

***Plant and Agricultural Biotechnology*** – Colorado is well positioned to assume leadership within the fast moving field of plant biotechnology. Existing Colorado plant bioscience assets include the National Seed Storage Laboratory at CSU, CSU's Departments of Bioagricultural Sciences and Pest Management, Soil and Crop Sciences, Biology, and program in Horticultural Biotechnology, and the University of Colorado's strengths in plant physiology.

***Biosecurity*** – The field of biosecurity is likely to experience tremendous growth as the United States and the world responds to a wide array of bioweapon threats. CSU and the CDC's labs in Fort Collins are leading a proposal that includes a number of regional research institutions for a regional center of excellence in bioterrorism and emerging infectious disease. Whether or not this center is funded, Colorado has existing assets, including the CDC lab in Fort Collins, which could contribute to developing a counter-terrorism research and commercial sector.

Over the longer term, additional focus areas that appear to have market potential in the mid-to-long term would be identified. These may include metabolics, which examines the chemical changes in an organism generating energy or materials required for life processes, computational biology/bioinformatics, and biomedical lasers and optics. Table ES-4 shows how the current and emerging strengths of Colorado's research institutions relate to the proposed technology platforms.

Special attention should be paid to promoting the convergence of health care and biosciences with other areas including information technology, optics, robotics, and microelectronics to create personalized or "genomic" medicine.

**Table ES-4: 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 (Next Five Years)** | | | |
| **Pharmaceutical Biotechnology** | Biological and Medical Sciences | Clinical Research<br>Pharmaceutical Sciences and Pharmacology<br>MCD Biology<br>Microbial Pathogenesis<br>RNA Biochemistry<br>Structural Biology<br>Genomics<br>Proteomics<br>Computational Biology<br>Bioprocessing | • Drugs/Therapeutics for Mycobacterial Diseases<br>• Neurological Drugs<br>• Cancer Drugs<br>• Diabetes Drugs<br>• AIDS Drugs<br>• Psychiatric Drugs |

| Technology Platform | Basic Research | Enabling Technology | Applications |
|---|---|---|---|
| **Areas Judged by Battelle to Have Near-Term Growth Potential (Next Five Years)** | | | |
| **Medical Devices and Bioengineering** | Engineering | Chemical Engineering<br>Polymer Science<br>Biomaterials<br>MEMS/Nanotechnology<br>Electrical Engineering<br>Mechanical Engineering | • Implantable materials<br>• Bioscaffolds<br>• Tissue Engineering<br>• Orthopedics<br>• Drug Delivery<br>• Intelligent Devices<br>• Diagnostic Instruments<br>• Biosensors |
| **Plant Biotechnology** | Plant and Agricultural Sciences | Plant Genomics<br>Crop Breeding<br>Transgenic Plants<br>Germplasm Preservation<br>Plant Pathogens<br>Bioprocessing<br>Biotech Risk Assessment<br>Environmental Sciences | • Transgenic Plants with pest/pathogen resistance<br>• Pharmaceuticals via Plant Pathways<br>• Bioprocessing of "Farmaceuticals"<br>• Environmental Monitoring |
| **Biosecurity** | Microbiology | Immunology and Infectious Diseases<br>High Level Biocontainment<br>Pharmaceutical Sciences and Pharmacology<br>MCD Biology<br>Microbial Pathogenesis<br>Microbiology and Vector-Borne Diseases<br>Bioprocessing<br>Environmental Sciences | • Vaccines<br>• Diagnostics<br>• Drugs and Therapeutics<br>• Environmental Monitoring |
| **Metabolics** | Metabolics | Clinical Research<br>Metabolics<br>Immunology<br>Endocrinology<br>Nutrition<br>Cell Biology<br>Cancer Biology/Carcinogenesis | • Cancer Drugs<br>• Anti-Inflammatory Therapeutics<br>• Pro-Inflammatory Therapeutics<br>• Analytical Instruments |
| **Computational Biology & Bioinformatics** | Mathematics and Computer Science | Mathematics<br>Computer Science<br>Statistics<br>Genomics<br>Proteomics<br>Biological Sciences | • Basic Science Discoveries<br>• Drug Discovery and Development |
| **Biomedical Lasers and Optics** | Physics | Mechanical and Electrical Engineering<br>Laser Physics<br>Optical Physics<br>MCD Biology<br>Biochemistry and Chemical Engineering | • Analytical Instruments<br>• Measuring Devices<br>• Surgery and Invasive Diagnostics<br>• Advanced Biomedical Imaging |

## Address the Complexity of the Bioscience Research and Industry Enterprise Through Cooperative Endeavors.

The bioscience sector stands out from other technology sectors in the close relationship that exists between the research and industry enterprise. Major new products and innovations in the biosciences are frequently related to basic research discoveries while in other technology sectors

the links are less direct. On average, biotechnology companies spend over 50 percent of their revenues on R&D, while pharmaceutical companies spend more than 20 percent. Across all industries, Standard and Poor's Compustat database estimates that industry R&D represents approximately four percent of sales. As a result, bioscience companies seek close interactions with academic researchers. Major university and non-profit research institutions are not only the key to basic research discoveries that can generate product leads for bioscience companies, but more importantly create an environment in which bioscience companies can flourish.

Colorado has both a base of bioscience companies and leading research institutions yet these research institutions are not closely tied to industry. In order to grow Colorado's bioscience sector, closer collaboration between industry and academic researchers will be required. To achieve such collaboration will require that industry develop a greater understanding of the mission of the research institutions and the incentives that drives behavior of researchers and faculty, and that the research institutions provide access and respond to industry and entrepreneurs.

Multi-disciplinary and cross-institutional linkages will also be required to develop the type of research excellence described above. For example, The University of Colorado Center for Pharmaceutical Biotechnology is linking CU Health Sciences Center Pharmacology with the Boulder-based disciplines of Pharmaceutical Sciences and Chemical and Biological Engineering. The Center is serving a coordinating role in a range of research areas and serves as a conduit for a significant number of pharmaceutical and biotechnology company-funded projects. If Colorado is to develop a cluster in the pharmaceutical biotechnology area, the center will need to extend its interaction with Colorado State University and other state bioscience research establishments. Another example is the proposed Rocky Mountain Institute for Biosecurity Research at CSU that is integrating statewide and regional expertise in infectious diseases, plant and animal biological agents and atmospheric sciences under one umbrella organization to coordinate and plan projects to meet pressing needs.

Similarly research and education initiatives that provide essential multi-disciplinary programs that will bring critical support to the bioscience industry need to be supported through their early phases. A good example is the computational biology program, which is a collaborative effort among CU campuses and located at the Denver campus.

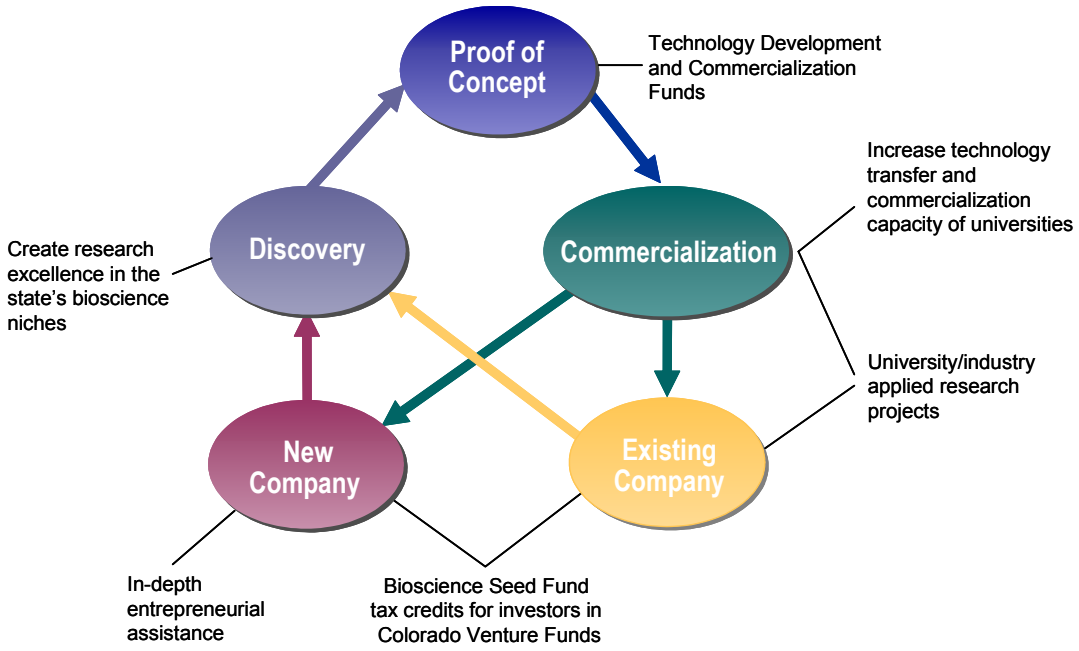
The Colorado Tobacco Research Program (CTRP) has been another successful multi-disciplinary and cross-institutional program. The CTRP supports comprehensive clinical, basic science, mental health, and evaluative research that serve Colorado's tobacco and substance abuse related health care needs. This approach serves as a good example of how to build relationships across disciplines and institutions to address complex issues and also bridge state policy priorities to the bioscience research and industry communities.

Lastly, the interrelationship of state policy and the biosciences will need to be recognized. The bioscience industry is a regulated industry and as such is impacted by federal and state health and regulatory policies. It will be important that state and local governments work cooperatively with the bioscience industry to ensure that policies are not enacted that would discourage the development of the biosciences in Colorado.

## THEMES AND ACTIONS: AN ACTION AGENDA TO POSITION COLORADO IN THE BIOSCIENCES

To move Colorado from having an emerging biosciences sector to the biosciences being a foundation of Colorado's economy, will require an innovation climate in which research is advanced toward commercialization, there are proactive technology transfer interfaces, and new companies are created and emerging companies succeed and grow. Figure ES-4 presents the components of Colorado's bioscience plan that address each stage of the innovation cycle.

**Figure ES-4: Overview of Colorado's Bioscience Plan.**




Three strategies are proposed to grow Colorado's bioscience cluster.

- **Strategy One**: Create a business climate sensitive to and supportive of the needs and issues facing bioscience firms.
- **Strategy Two**: Grow the state's bioscience cluster by creating a bioscience entrepreneurial culture that turns research discoveries into new products and services and cutting edge firms and provides appropriate incentives to research institutions and industry.
- **Strategy Three**: Expand the research base and build research excellence in the state's bioscience niches.

Table ES-5 lists the proposed strategies and actions which are described below.

**Table ES-5: Summary of Proposed Strategies and Actions**

| Strategy | Action |
|---|---|
| **STRATEGY ONE: Create a business climate sensitive to and supportive of the needs and issues facing bioscience firms.** | Enact a package of tax incentives to be triggered as the state's economy improves, to support the growth of Colorado's bioscience companies. |
| | Appoint a high-level Bioscience Advocate within state government. |
| | Review and ensure that state Medicaid policies relating to pharmaceuticals do not discourage building the bioscience industry in Colorado. |
| | Strengthen the voice of the bioscience industry in Colorado by forming a unified Bioscience Industry Association. |
| | Create a focus on the biosciences within the Governor's Office of Economic Development and International Trade. |
| | Develop and implement an industry-led, comprehensive communications strategy to educate and inform citizenry, elected officials, the nation and world about Colorado biosciences. |
| | Use the Colorado Institute of Technology to work with industry to identify and address emerging bioscience workforce needs at all levels. |
| **STRATEGY TWO Grow the state's bioscience cluster by creating a bioscience entrepreneurial culture that turns research discoveries into new products and services and cutting edge firms and provides appropriate incentives to research institutions and industry.** | Provide comprehensive in-depth entrepreneurial assistance to bioscience entrepreneurs and companies. |
| | Create a privately managed Colorado Bioscience Seed Fund and encourage a bioscience focus for angel investor networks. |
| | Enact legislation that would use state tax credits to guarantee investments in a "fund of funds" that would invest in private venture capital companies willing to invest in Colorado companies. |
| | Undertake activities that celebrate successful bioscience role models. |
| | Explore opportunities to establish plant-and animal-based pharmaceutical and nutraceuticals production within Colorado. |
| | Continue to build and strengthen technology transfer/commercialization capacity of universities. |
| | Create Technology Development Funds to support proof of concept and other commercialization activities. |
| **STRATEGY THREE Expand the research base and build research excellence in the state's bioscience niches.** | Complete full physical development of UCHSC/UCH Fitzsimons Campus to help anchor Colorado's bioscience research base for the future. |
| | Encourage collaborative partnerships between academic researchers and industry by providing funding for collaborative university/industry applied research projects, streamlining industry contracting, and designating an industry liaison. |
| | Identify opportunities and compete for national and federal institutes and centers of excellence in Colorado's bioscience niche areas. |
| | Develop a pilot program of product development and technical assistance support for the medical device, advanced manufacturing and bioagriculture development industries. |

**Strategy One: Create a business climate sensitive to and supportive of the needs and issues facing bioscience firms.**

**Action One: Enact a package of tax incentives, to be triggered as the state's economy improves, to support the growth of Colorado's bioscience companies.** Traditional tax incentives put in place to encourage the establishment and growth of companies—tax credits for job creation and investment—generally do not benefit young bioscience companies. In 1999, Colorado enacted legislation that allows qualified taxpayers to obtain a refund for Colorado sales and use taxes paid on purchases of personal property used directly and predominantly in R&D of biotechnology. It is recommended that Colorado develop a legislative package of additional tax incentives to encourage the growth of emerging bioscience companies that would be triggered as the state's economy improves. Consideration should be given to:

- Allowing biotechnology companies to sell unused Net Operating Loss (NOL) carryover to another tax payer.
- Allowing bioscience companies with unused amounts of research and development tax credits that cannot be applied in the credit's tax year to transfer those credits for use by other corporation business taxpayers in the state. Consideration could also be made to making R&D tax credits refundable.

**Action Two**: **Appoint a high-level Bioscience Advocate within state government.** Colorado is fortunate in that it has multiple organizations that are seeking to promote the development of the state's bioscience cluster. There is, however, no single point of contact that speaks for, or represents, the entire spectrum of bioscience interests. Nor is there a point of contact in state government for the bioscience industry. It is recommended that Governor Owens appoint a Bioscience Advocate, similar to the Aerospace Advocate, to be housed within the Governor's Office of Innovation and Technology. The appointment of a Bioscience Advocate will demonstrate the state's commitment to developing and supporting Colorado's bioscience sector. The Advocate will work closely with the bioscience sector, including both industry and academia, to identify needs and develop proposals to address those needs. The Bioscience Advocate will be responsible for coordinating implementation of the Colorado Bioscience Plan and tracking progress.

**Action Three: Review and ensure that state Medicaid policies relating to pharmaceuticals do not discourage building the bioscience industry in Colorado.** While many states are investing in initiatives designed to grow their bioscience sector, states are also passing legislation to limit the cost of prescription drugs or place limits on the use of certain drugs by Medicaid patients. Such policies can have an adverse impact on the very bioscience companies that these states are seeking to develop. Colorado should review the state's Medicaid policies relating to pharmaceuticals to ensure that these policies do not inadvertently discourage the building of the bioscience industry in the state.

**Action Four: Strengthen the voice of the bioscience industry in Colorado by forming a unified Bioscience Industry Association.** Technology regions across the country have found it extremely important to have membership-driven networking and advocacy organizations that work within an industry or technology sector to address common needs and problems and to build image and awareness of the industry and related assets. Colorado has two organizations, the Colorado Biotechnology Association and the Colorado Medical Device Association, that

represent various components of the bioscience industry. In addition, there are several other organizations, including the Colorado Alliance for Bioengineering, that undertake similar activities such as holding networking events and seeking to promote partnerships between bioscience companies and Colorado universities. The ability of each of these organizations to advocate on behalf of the bioscience sector and to facilitate the intensive networking required to support the growth of the biosciences is constrained by resources. A single, unified Colorado Bioscience Association should be established. The Association should:

- Serve as a clearinghouse for information on the biosciences in Colorado. The association can provide a forum for bioscience companies and academic research institutions to exchange information on issues related to the biosciences and maintain data on Colorado's bioscience industry cluster;
- Advocate on behalf of the biosciences, identifying needs and developing proposals for policies and programs to address these needs;
- Act as a matchmaker and networker—the association can help connect groups and organizations and make them aware of opportunities. It can hold various events to bring higher education and industry representatives together to learn about trends and developments; and,
- Promote the image of Colorado as a center of the biosciences. The industry association can help publicize, inform, and educate the public through the media and through the events and programs it sponsors about the biosciences and its contribution to the Colorado economy.

The economic development community should work with the bioscience industry association in accomplishing these goals.

**Action Five: Create a focus on the biosciences within the Governor's Office of Economic Development and International Trade.** The Governor's Office of Economic Development and International Trade markets Colorado for business and tourism development and assists companies interested in relocating to or expanding in Colorado. The state has few of the economic development incentive programs that other states use to assist companies directly, with the exception of a job training program that assists companies with customized job training. It is recommended that the state of Colorado undertake a business development effort focused on marketing the bioscience assets of the state and assisting bioscience companies wishing to locate in Colorado. Specific initiatives could include:

- Creating a state-level bioscience marketing team to coordinate participation in industry trade shows, developing lead generation efforts, and responding to inquiries from bioscience companies interested in locating in Colorado;
- Establishing an integrated, statewide, one-stop bioscience company response team that will ensure quick turnaround on permitting, deal packaging, research partners, and other needs of bioscience companies; and,
- Undertaking trade missions focused on domestic and foreign markets that provide opportunities for the biosciences.

**Action Six: Develop and implement an industry-led, comprehensive communications strategy to educate and inform citizenry, elected officials, the nation, and the world about Colorado's biosciences.** For this bioscience plan to be successfully achieved, various groups and

organizations across the state must come together to support its implementation. But, to do this is not easy or simple. The stakeholders will need to be committed to this effort for the long term; states do not build bioscience clusters overnight. And it will require a considerable degree of collaboration and connectivity among the various entities willing to work over many years for the common good of the state.

It is proposed that an industry-led campaign be undertaken to build awareness among state policymakers, business and community leaders, and the state's citizenry of the strengths of Colorado in the biosciences and the benefits to be derived from developing the state's bioscience sector. The bioscience industry association needs to assume a leadership role in accomplishing these goals. Specific actions that should be taken include:

- Engaging in ongoing, continuous dialogue with legislators and opinion makers on the importance of the biosciences and its contribution to Colorado's economy;
- Holding an Annual Bioscience Summit as part of an existing bioscience state event, such as BioWest;
- Organizing delegations to represent Colorado at national conferences, such as BIO; and,
- Undertaking public outreach and educational activities.

**Action Seven: The Colorado Institute of Technology should work with industry to identify and address emerging bioscience workforce and education needs at all levels.** Existing Colorado bioscience companies indicated in interviews that they are generally able to find workers with the skills they need, although in some cases they must go out of state to recruit senior employees with experience in the biosciences. Some companies indicated that they had difficulty filling some positions such as medical technicians. While workforce does not appear to be a limiting factor at the moment, over time as the bioscience sector grows, there will be need for an increasing number of bioscience workers. Colorado is fortunate to have a highly educated population and an available workforce and educational institutions that will be able to provide the training needed to prepare people to become bioscience workers. The challenge will be to identify skill needs, to develop appropriate curricula, and to establish and fund programs for workers in this rapidly changing field.

In addition to ensuring that current and near term workforce needs are addressed, emphasis must be place on working with industry and the state's research institutions to identify the degrees, programs, and courses that will be needed to position Colorado to grow the state's bioscience niches. Increasingly interdisciplinary and multi institutional programs are required to educate, train, and graduate the future bioscience workforce. Those universities that are quickest to incorporate the results of technological advancements into their curriculum will have a lead in producing the talent needed by bioscience firms, particularly in multi-disciplinary fields that support Colorado's' bioscience competencies.

Colorado's research institutions have begun initiatives, such as the CU Center for Computational Biology, to address some of these needs already. The Center has launched certificate, masters, and PhD. Programs in computational biology, bioinformatics, and computer sciences. For Colorado to fully leverage its areas of key bioscience research strengths, enhanced capabilities in not only computation biology but in other areas such as bioengineering will be needed.

CIT serves as the central strategic planning entity that is charged with analysis assessing industry needs and higher educational institutions' capacity to respond. It is proposed that CIT work with Colorado's research institutions and industry to identity the degrees, program and courses that will be required to advance this bioscience plan and ensure that funding is available to establish and grow programs like the Center for Computational Biology. The technology platforms that offer the greatest opportunities for growing Colorado's bioscience sector and the programs and educational offerings required to support their development are identified in the core competency report prepared as part of the development of this plan.

Lastly, addressing the bioscience pipeline of future workers also is critical. A focus is required both on K–12 education and on technician-level education in community colleges, two areas from which the bioscience industry traditionally has not drawn it workforce but likely will in the future. CIT should work with the bioscience industry association to identify and address needs for K–12 and technician level education.

**Strategy Two: Grow the state's bioscience cluster by creating a bioscience entrepreneurial culture that turns research discoveries into new products and services and cutting edge firms and provides appropriate incentives to research institutions and industry.**

**Action One: Provide comprehensive in-depth entrepreneurial assistance to bioscience entrepreneurs and companies.** One of the goals of Colorado's Bioscience Plan is to grow a critical mass of bioscience companies by encouraging new firm creation. This will require encouraging entrepreneurs and providing support to new start-up companies. Colorado has a number of organizations including industry associations, incubators, the Colorado Bioscience Park Aurora, local economic development organizations, and university technology transfer offices that provide some level of support to entrepreneurs and new start-up companies. These organizations should work jointly to create more in-depth programs for entrepreneurship education, and provide training, coaching and mentoring specifically targeted to bioscience companies. Services to be provided through these programs could include technology and market assessments, providing assistance in applying for Small Business Innovation Research (SBIR) and other grant programs, help in developing a business plan, and help in identifying and accessing sources of capital. The universities' business schools should be further engaged to assist in providing assistance to entrepreneurs and faculty seeking to commercialize research findings and/or interested in starting new ventures.

**Types of Capital Needed by Bioscience Firms**

- ***Commercialization funding,*** which can be used to assess and undertake a review of the commercial potential of completed R&D.
- ***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 initial public offering. Given the long time frame required for the regulatory review process, bioscience firms will often require multiple rounds of venture financing.

**Action Two: Create a Colorado Bioscience Seed Fund and encourage the formation of bioscience angel capital networks.** While Colorado companies in general have a good track record in terms of attracting venture capital, and Colorado bioscience firms have been successful in attracting

outside later stage venture capital investment, there is a lack of very early stage seed and pre-seed capital for entrepreneurs and start-up bioscience companies. To address this need, the creation of a Colorado Bioscience Seed Fund is proposed. Such a fund would provide post-angel but pre-formal venture financing in the range of $150,000 to $2 million size investments. It is proposed that the fund be privately managed. Potential sources of capital are private investors, university foundations, and state pension funds. The Fund would target itself to raise $35–70 million for its initial capitalization. To address the need for even earlier, smaller levels of investment, the creation of bioscience angel capital networks should be encouraged.

**Action Three: Enact legislation that would use state tax credits to guarantee investments in a fund of funds that would invest in private venture capital companies willing to invest in Colorado companies.** Although some Colorado bioscience companies have been successful in obtaining venture capital, the majority of this capital has come from out of state funding sources. Over the long term, it will be important for Colorado to develop additional locally-based venture funds willing to invest in bioscience companies. It is proposed that Colorado enact legislation authorizing creation of a "fund of funds" that will invest in private venture capital funds that commit to investing in Colorado. Money for the fund of funds would come from the sale of stock to institutional investors such as banks and insurance companies, with the preferred stock having guaranteed dividend and redemption features. Tax credits would be used to collateralize the guarantees. Therefore, the credits would be used only if the cash flow from the fund of funds is insufficient to meet the obligations granted in the preferred stock. This proposed program would be similar to one that has been in place in Oklahoma since 1992. (See text box.) Legislation for similar programs has been enacted in Iowa and Utah. One advantage of this approach is that the fund of funds can direct investments to venture capital funds that invest in particular types of companies, such as bioscience companies.

**Oklahoma Capital Investment Board**

In 1992, Oklahoma created the Oklahoma Capital Investment Board (OCIB) to encourage equity and near-equity investments in private venture capital partnerships. The capital OCIB invests comes from institutional lenders and investors through the Oklahoma Capital Formation Corporation. The principal and interest on OCIB's borrowed funds are guaranteed if necessary by $50 million in tax credits with limits of $10 million of tax credits per year. State tax credits will be used only in the case that investment returns are insufficient to meet OCIB's guarantee commitments. Since its inception, OCIB has invested in eight private limited partnerships investing a total of $26 million. These funds have drawn down $18 million and invested (including co-investors) $66 million in 11 Oklahoma companies. The annual rate of return since inception has been 29.6 percent.

In addition, it is proposed that legislation be introduced to provide state tax credits to individuals that invest in Colorado based bioscience-focused seed and later stage venture funds. In light of the state's current fiscal situation, the tax credit would be triggered at a predetermined point as the state's fiscal situation improves.

**Action Four: Undertake activities that recognize successful bioscience role models**. One lesson from successful bioscience regions is that role models and entrepreneurial success stories are key parts of winning efforts to build entrepreneurial cultures. If Colorado wants to develop its bioscience cluster by growing its own bioscience companies, it will be important to convey to its citizens the opportunities presented by the biosciences and the success that has been and can be achieved by bioscience entrepreneurs. Colorado has a number of industry association and development organizations that seek to promote and build awareness of the biosciences in

Colorado. The Colorado Biotechnology Association, Colorado Medical Device Association, Colorado Venture Centers and the Fitzsimons Redevelopment Authority, for example, hold monthly BioBreakfasts that provide opportunities to showcase bioscience companies. In October 2002, the first BioWest conference was held, which also provided an opportunity to highlight Colorado bioscience company success stories. These efforts should be continued and expanded. It is also proposed that a **Colorado Bioscience Entrepreneur of the Year Award** be established to reward and encourage successful bioscience entrepreneurs who will become the roles models for the next generation. A Colorado Bioscience Entrepreneur of the Year award will also promote the importance of the biosciences to Colorado's economy.

**Action Five: Explore opportunities to establish plant and animal-based pharmaceutical and nutraceutical production within Colorado.** Colorado has been identified as a target market for ag-biotechnology for the production and processing of transgenic crops genetically engineered to produce pharmaceuticals and nutraceuticals. Recent advances in technology which enables genes for specific drugs to be inserted into major agricultural crops opens the possibility for revolutionary change in pharmaceutical and specialty chemical production. Using plants to produce drugs offers the possibility of greatly reducing the cost of transgenic drugs. Despite the opportunities this poses, there are also significant production related issues that arise with the movement of the production of active pharmaceuticals from a carefully controlled environment to an uncontrolled outdoor environment. A number of communities in Colorado are already investigating opportunities for plant and animal pharmaceutical and nutraceuticals production. Elbert County, for example, has produced an Opportunity Assessment Plan and Adams County is also pursuing a similar initiative. It is recommended that Colorado move quickly to assess opportunities and develop an action plan to position Colorado to take advantage of this emerging bioeconomy.

**Action Six: Continue to build and strengthen technology transfer/commercialization capacity of universities.** It is generally acknowledged that in the past, Colorado's universities have not emphasized technology transfer and commercialization. Despite this fact, a number of Colorado's successful bioscience companies have been founded by faculty and researchers from the universities. But during the last two years, the Colorado School of Mines, Colorado State University and the University of Colorado have each strengthened their commitment to technology transfer. In 2002, the University of Colorado system developed its first ever Strategic Plan for Technology Transfer, which sets a goal of being recognized as the best technology transfer office among public universities by 2010. The Colorado State University Research Foundation is implementing a Strategic Plan for Technology Transfer that was adopted in 2000. The universities should continue to emphasize the importance of commercializing research findings and provide the necessary support needed to operate effective

**Boston University's Community Technology Fund**

The Community Technology Fund (CTF) is Boston University's (BU) name for its combined licensing office, commercialization function, and direct-investment fund. A separate unit of CTF, called "New Ventures," is responsible for developing new start-up companies based on BU technologies.

New Ventures makes "technology development awards" that are designed to "bridge the gap between government funded basic science and the more developed technologies that are of interest to commercial entities." The grants, which range from $20,000 to $50,000 but can be up to $100,000 under special circumstances, can be used to finance commercialization research or reduction to practice. Projects are selected based upon commercialization potential and the feasibility that the award will increase the value of a technology or the likelihood that it will be commercialized. The awards are not repayable.

technology transfer operations.

**Action Seven: Create Technology Development Funds to support proof of concept and other commercialization activities.** It is recommended that Technology Development Funds be established within each Colorado research institution that would provide financial support to ascertain the commercial potential of research findings and to move research toward commercial applications. The fund would provide funding in the range of $25,000 to $100,000 to undertake due diligence to determine commercial potential. This level of funding is needed to bridge the gap between basic science conducted at Colorado's research institutions and the development of technologies with commercial potential. The fund would make awards to be used to increase the value of a technology and to develop it to the point at which its commercial potential has been demonstrated. Awards could be used to develop a prototype or conduct further research that helps determine market value. The funds could seek contributions from alumni, foundations and high net worth individuals.

## Strategy Three: Expand the research base and build research excellence in the state's bioscience niches.

**Action One: Complete full physical development of UCHSC/UCH Fitzsimons Campus to help anchor Colorado's bioscience research base for the future.** The State of Colorado and the University of Colorado have committed to relocating UCHSC and UCH to a state of the art medical campus at Fitzsimons. The Children's Hospital is also relocating to the campus from its current location in Denver. The campus on which the University and hospitals are located is linked to the 160 acre Colorado Bioscience Research Park Aurora, which will house university-affiliated and emerging bioscience companies. The Fitzsimons site provides the opportunity to create an interactive community of bioscience research, teaching and patient care.

> There is great anticipation of an influx of positive economic growth...The combination of UCHSC/UCH and a huge bioscience research park will bring industry to the area. It will be a transfer between the basic sciences and the practical world."
>
> James H. Shore, MD, Chancellor, University of Colorado Health Sciences Center

The initial phase of the move of UCHSC and UCH to Fitzsimons is estimated to cost $1.3 billion, which will result in an increase from 2.7 million gross square feet on 46 acres at the current location to 3.4 million gross square feet on 217 acres at the new location. Another 1.5 million gross square feet of space, mostly for research is slated for construction following the initial transition period.[13] Completion of the entire Fitzsimons building program will require a total capital investment of nearly $4 billion.

The university has proposed that the state issue Certificates of Participation (COP) to fund the completion of its portion of the Fitzsimons academic development, which totals $202 million.[14] The COP would be issued for $202 million over 25 years, requiring a $15.1 million annual

[14] Under this proposal, the state would enter into lease-purchase agreements to build capital facilities. If approved, the state's annual lease payments will be marketed to investors as certificates of participation. A "certificate" refers to an investor's proportionate interest in the state's lease payments.

contribution from the state. Funding for the $15.1 million would come from a variety of sources. Legislation to authorize the COP for Fitzsimons is currently under consideration by the Colorado legislature. Enactment of this legislation will help move forward the development of the Fitzsimons campus, a key component in advancing the development of Colorado's bioscience cluster.

While the location of the UCHSC/UCH campus at Fitzsimons is a key anchor, Colorado should work with its Congressional delegation to identify opportunities for federally supported facilities to locate at Fitzsimons. One facility already identified is the VA Medical Center. The relocation of the VA Medical Center to Fitzsimons should continue to be pursued as it would provide another important anchor for the campus and would be a key component in the network of institutions providing patient care, biomedical research, education and biotechnology R&D at the Fitzsimons site.

**Action Two: Encourage collaborative partnerships between academic researchers and industry by providing funding for collaborative university/industry applied research projects, streamlining industry contracting, and designating an industry liaison.**

As discussed above, it is commonly acknowledged that Colorado's universities do not have a strong history of collaborating and connecting with industry. For Colorado to become a leading bioscience center, it needs to build sustained relationships between its bioscience companies and the state's research institutions. One way to accomplish this is to provide funding for collaborative university/industry applied research projects. Such projects help build relationships between researchers and companies and provide support for activities that help to move technology to the point where private investment capital can be obtained.

At least a dozen states have matching grant programs that provide an incentive for firms to support research projects at local research institutions. One such program is Utah's Centers of Excellence Program. The Utah program is somewhat misnamed as it is really a project grant program, not a centers program. Nevertheless, it represents an example of a challenge grant program intended to create enduring academic/industrial partnerships that lead to ongoing support and commercialization of intellectual property within the state. Budgeted at about $2 million a year, the Centers program supports about 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. 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 Center program is credited with the creation of 150 new companies and 204 license agreements. Another program designed to promote industry universities partnerships that is focused exclusively on the biosciences is California's BioStar program, which is described in the text box.

**BioSTAR**

An excellent example of an industry/university matching grant program in the biosciences is the University of California's Biotechnology Strategic Alliances in Research (BioSTAR) program. Established in 1996, this mechanism links life science companies with researchers in their field through a modest matching grant. BioSTAR involves a highly competitive process in which research proposals are peer reviewed and companies must provide at least half the cost of the project. Since its inception, BioSTAR has fostered linkages between many of California's small, emerging, life science companies and the University of California campuses, providing a highly valuable competitive edge to its emerging, small, life science companies.

National best practice suggests that matching grant programs are the most effective method when compared with other types of university/industry partnerships that exist to promote technology commercialization. Another approach to providing funding for higher education/industry partnerships is to use tax credits to build stronger and more sustained relationships between state industries and research institutions. It is proposed that Colorado create a project matching program or R&D voucher program that would provide funding for industry research projects conducted by Colorado research institutions. It is proposed that funding be provided in the range of $125,000–$250,000. The industry partner must match the state funds on a 3:1 basis. The annual budget for this program would be approximately $2–$2.5 million annually.

Another action that the universities can take to encourage more collaborative research with industry is to streamline industry contracting procedures and make them more user friendly. Lastly, there is a need to continue dialogues to build greater understanding on the part of faculty of industry needs and requirements and on the part of industry of university missions and requirements. The Colorado Biotechnology Association should take the lead in helping industry to learn how to access and partner with universities. For their part, each of the research institutions need to commit to being responsive to industry requests. It is recommended that each research institution designate an industry liaison to serve as an initial point of contact for industry wishing to find industry researchers with which to interact.

**Action Three: Identify opportunities and compete for national and federal institutes and centers of excellence in bioscience niche areas.** Increasingly states, through their public and private representatives, have been working closely with their Congressional Delegations to ensure federal investments are made that help create the research and research infrastructure anchors that help build bioscience economies. As noted in the description of best practices, one key lesson for state 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 U.S. has one or more federal anchors that have contributed to building its bioscience base, e.g., 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 various bioscience areas.

In order to develop research excellence in selected areas, Colorado's research institutions will have to come together to collaboratively pursue opportunities for federal and other sources of research funding. A good example of where this has happened recently is the proposal that has been submitted to the National Institute of Allergy and Infectious Diseases for a regional center of excellence in bioterrorism and emerging infectious diseases by a coalition of regional research institutions led by CSU and the CDC laboratory in Fort Collins.

**Action Four: Develop a pilot program of product development and technical assistance support for the medical device, advanced manufacturing and bioagriculture development industries.** One potential way to bring firms, particularly small and medium sized device firms, into closer contact with research organizations is by forming a pilot demonstration program whereby a product development/technical assistance center can be established at one of the University campuses in Colorado. Alternatively, the bioprocessing scale up facility at CSU could be used to house such a center. This effort should be undertaken as a pilot project to determine whether such a center would be effective in creating relationships and communications between

industry and academe. If successful, additional pilot centers serving other industries can be considered or the pilot program could be expanded and made permanent.

## IMPLEMENTATION PLAN

Colorado is well positioned to grow its bioscience cluster. But if Colorado is to succeed in capturing significant growth in this sector, it must act quickly as other states and regions are aggressively making investments to attract and grow their bioscience sectors. If Colorado is to achieve its vision for the biosciences, it must rapidly implement the strategies and actions in this plan.

This plan has been developed with the support of the State of Colorado, Colorado's bioscience industry, the state's research institutions, and economic development organizations. Each of these stakeholders has a role to play in implementing the plan. But it is also important that one entity take responsibility for coordinating the efforts of the various players and monitoring progress. It is recommended that the management team that developed the Plan and the state's Bioscience Advocate play this coordinating and monitoring role. It is further proposed that the bioscience industry, through the Bioscience Industry Association, take lead responsibility for implementing the Plan and leveraging other stakeholders to take responsibility for key elements of the plan.

In addition to the Colorado Bioscience Industry Association, key stakeholders responsible for implementing various actions include:

- Governor's Office of Economic Development and International Trade;
- Colorado's research institutions, with leadership from the University of Colorado and Colorado State University;
- Colorado's economic development organizations, with leadership from the Metro Denver Chamber of Commerce and other chambers and economic development organizations throughout the state; and,
- Colorado Institute of Technology.

It is recommended that each of the stakeholders identify and commit to implementing the actions appropriate to their organization.

### Priority Actions

In light of the economy and the current fiscal condition of the state, it is important to identify those actions that are likely to have a direct impact on the development of Colorado's bioscience sector. It is recommended that the following actions be undertaken immediately.

1. Appoint Bioscience Advocate within state government.
2. Continue to build and strengthen technology transfer/commercialization capacity of universities, including creating technology development, proof of concept funds.
3. Complete development of UCHSC/UCH Fitzsimons Campus.
4. Strengthen the voice of the bioscience industry in Colorado by forming a unified Bioscience Industry Association.

5. Create a privately managed Colorado Bioscience Seed Fund and encourage creation of bioscience focused angel investor networks.
6. Explore opportunities to establish plant-and animal-based pharmaceutical production within Colorado.
7. Create a focus on the biosciences within the Governor's Office of Economic Development and International Trade.
8. Develop and implement an industry-led, comprehensive communications strategy.

### Measures of Success

It is recommended that the following measures be used to gauge success and progress in implementing Colorado's bioscience plan:

- Increase in bioscience R&D funding at Colorado research institutions equal to or greater than the national average.
- Increase in industry funding of bioscience R&D at Colorado research institutions to the national average for industry funding as a percent of total R&D funding.
- At least $100 million in federal and other bioscience dollars attracted to Colorado for centers and national institutes by 2008.
- Increase commercialization of bioscience technology developed at Colorado research institutions as measured by number of new start-ups and number and value of licenses.
- Growth in state's bioscience economic base: number of firms, their employment, their concentration in the state relative to the nation, and birth and death rates of firms.
- Indigenous venture capital dollars invested in Colorado bioscience companies will reach $50 million by 2008.
- Implementation progress on the actions laid out in the plan of at least 70 percent with substantial action after three years, and 90 percent within five years.

## CONCLUSION

Colorado is fortunate to possess strong assets in the biosciences that offer great potential for the state's economy. To date, the state's bioscience sector has developed largely by serendipity and if left alone would be likely continue to grow somewhat. But this sector has the potential to become a true driver of Colorado's economy.

Taking advantage of the opportunities provided by the biosciences in Colorado will require:

- Commitment and willingness to collaborate on the part of the public, private and academic communities;
- Achieving research excellence with national level focus in selected areas;
- Commitment on the part of Colorado's universities to a broad commercialization program to capitalize on technology transfer and entrepreneurial activities;

- Continued investment in bioscience infrastructure, including the completion of the Fitzsimons development; and,
- Commitment on the part of the State of Colorado to support the bioscience sector.

In the early years of the New Millennium, the biosciences have emerged as one of the most dynamic and growth-oriented sectors of the economy. Advances in the biosciences will likely revolutionize the economy of the coming decade, as telecommunications and computer technology did in the prior decade. Colorado has the opportunity to seize the opportunity presented by the biosciences and build an industry that will not only have economic development benefits but that can improve the health and well being of Colorado's citizens.

For additional information, please contact a member of the Colorado Bioscience Plan Management Group:


***David N. Allen, Ph.D.***
Assistant VP for Technology Transfer
University of Colorado
Boulder, CO
303-735-1688
David.Allen@cu.edu

***Denise Brown***
Executive Director
Colorado Biotechnology Association
Aurora, CO
720-859-4153
dbrown@colobio.com

***Chad DeLong***
Director of Economic Development
Denver Metro Chamber of Commerce
Denver, CO
303-620-8066
chad.delong@den-chamber.org

***John Louviere***
Colorado Institute of Technology
Broomfield, CO
303-866-6250
jlouviere@coloradoit.org

***Arundeep S. Pradhan***
Director of Technology Transfer
Colorado State University
Research Foundation
Fort Collins, CO
970.482-2916
arundeep.pradhan@csurf.colostate.edu

***Paul Ray***
Director
Office of Life Sciences and Biotechnology
Colorado Office of Innovation
and Technology
Broomfield CO
303-866-6060
Paul.Ray@oit.state.co.us

***Christine Snowberger***
Colorado Office of Economic
Development and International Trade
Denver, CO
303-892-3850
chris.snowberger@state.co.us