

# Biotechnology Assessment Report

for the



and the



TENNESSEE  
BIOTECHNOLOGY  
ASSOCIATION

THE QUALITY OF LIFE SCIENCES

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*Prepared by:*



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# ***Biotechnology Assessment Report***

## **Executive Summary**

Biotechnology is on the minds of economic development agencies across the United States. Nearly 85% of local development agencies place biotechnology as one of their top two priorities. There are 41 states that have active biotech programs. If Tennessee is to become and remain competitive in this important field, it must understand what biotechnology research and industry currently exists in the state and determine the best plan for stimulating biotechnology growth in Tennessee.

The Tennessee Technology Development Corporation (TTDC) and the Tennessee Biotechnology Association (TBA) commissioned Science Applications International Corporation (SAIC) to perform a study of Biotechnology in Tennessee. This study is an outgrowth of the 2002 “Report of the Governor’s Task Force on Biotechnology”. It was commissioned to determine the current status of the biotechnology industry in Tennessee and make recommendations designed to promote the future development of the industry.

A broad spectrum of companies, institutions, and interested individuals, representing both those working directly in biotechnology and those in related or supportive fields, form a “biotechnology community” all of whom have a stake in the future of biotechnology in Tennessee. These individuals, companies, and institutions participated in a web Survey, a phone Survey, and face-to-face focus groups. The data was correlated and compared with results of literature searches to obtain a snapshot of the state of biotechnology in Tennessee and how it compares to other states. Through this study, some important strengths in Tennessee’s emerging biotechnology community and some important gaps were determined.

## **Primary Successes and Strengths**

Intellectual property (IP) transfer to the private sector and collaborative efforts are cornerstones for the advancement of biotechnology in the state. Tennessee has had some important successes in these areas. The University of Tennessee Research Corporation (UTRC), with offices at both the Knoxville and Memphis campuses, has had great success in IP transfer in biotechnology and biotechnology-related fields. The Vanderbilt University Medical Center (VUMC) has had a number of successful IP transfers. The Cumberland Emerging Technologies (CET) incubator, a cooperative venture between Cumberland Pharmaceuticals, the TTDC, and Vanderbilt University supplies the infrastructure required by researchers to transition their IP into startup companies. One of the greatest statewide collaborative efforts is the Tennessee Mouse Genome Consortium (TMGC); a collaboration between 10 major research institutions in the state.

To further capitalize on these successes and take the UT system to the next level in IP transfer and research collaboration, the UT Research Foundation (UTRF) has been developed as the successor to the University of Tennessee Research Corporation (UTRC). UTRF can provide UT’s researchers with important IP management. It can also provide necessary incubator

facilities as well as develop partnerships and alliances with the business community and state and Federal agencies.

Other strengths in Tennessee include its quality of life. While this encompasses many factors our low cost of living in particular may be a strength that can be used to our advantage. Cost considerations such as land, construction, taxes, utilities, and labor, which in Tennessee are far lower than those in other key biotechnology markets, can become a major factor in determining the location of production and distribution facilities.

Studies have shown that biotechnology companies strongly prefer to have their manufacturing operations as close as possible to their research and development (R&D) centers. High-caliber research institutions in Tennessee clearly account for the clusters of start-ups that currently exist and are certainly a positive factor when trying to grow these clusters. Survey data shows the beginnings of four clusters forming in Tennessee: Memphis, Nashville, and to a lesser extent Knoxville, and the Tri-Cities area. The Memphis and Nashville clusters are supported by the strong health care industry found in these areas.

Another strength that was noted in the Survey, and can easily be capitalized, was Tennessee's centralized location and excellent distribution infrastructure. This infrastructure is crowned by Federal Express in Memphis which serves as the major distribution service utilized by several Surveyed firms. This strength has been described as "bio-logistics" and promises to play a much larger role in the future as more companies move from R&D into processing of biological materials such as proteins.

### **Primary Gaps**

Quality of our workforce is one of our primary gaps in Tennessee. An inadequate workforce represents an enormous barrier to the growth of biotechnology in the state; and other surveys show that Tennessee does not rank in the top half of the states in any measurement related to education. But, this does not necessarily mean the emphasis needs to be put at the college and graduate school level. Tennessee should be interested in attracting mature biotechnology companies to the area. In the biotechnology company life cycle the point at which they will relocate is when they transition to manufacturing and distribution. Production workers needed by the more mature companies generally do not require four-year degrees. AA/AS degrees from a community college, or even a high school diploma, are frequently enough for an entry-level position.

One notable plan to address the shortage of skilled workers is the creation of a Memphis charter school, sponsored by the Memphis Biotech Foundation. The recently approved Memphis Academy of Science and Engineering (MASE), a grades 7-12 school, will be Tennessee's first charter school.

Access to venture capital is also an important gap in Tennessee. Studies have shown that venture capital firms strongly prefer to invest in companies that are local to their own offices. When compared to other states, Tennessee appears to suffer from an almost complete lack of venture capital for the biosciences.

Public policy in the form of tax incentives, a good regulatory climate, business incubators, and support for publicly funded research institutions is an additional crucial gap noted by Survey respondents. Long lead times required to bring biotechnology products to market require highly supportive and stable tax and regulatory policies. These tax policies can provide additional capital for emerging companies, as well as ensure an even playing field between older, traditional industries and emerging high-technology industries such as the biosciences.

Several initiatives are already underway to close these gaps, such as the proposed Research Tax Credit. But for a state to develop a significant presence in biotechnology, that state must make a concerted, long-term commitment. Tennessee needs a long-term plan to achieve this goal, as the payoffs will not come for 10 years or more.

### **Next Steps**

The initial Survey is complete; there is a baseline, method, and format for the data. Tennessee has clusters of biotechnology that are beginning to form. Tennessee's strengths are in IP transfer mechanisms, quality of life, and distribution capabilities while its weaknesses are the skills of the workforce and the lack of venture capital and supportive public policy. Tennessee's next steps should reference the following:

- A concerted effort needs to be made to continue measuring the biotechnology presence in Tennessee
- Agencies, such as the Tennessee Biotechnology Association, need to continue to promote networking among our companies and researchers
- Our public officials need to support the changes necessary for the growth of biotechnology in Tennessee
- A further, more specific, survey should be undertaken to research more specific questions targeted at developing specific initiatives
- A metrics plan should be established to monitor the effectiveness of all of these actions.

With our low costs and excellent distribution, Tennessee may be able to attract these firms to locate manufacturing facilities here. One strategy for Tennessee may be to promote the development of pilot manufacturing plants and contract manufacturing facilities. **Moreover, Tennessee needs to make a long-term commitment now, provide a stable and supportive environment for biotechnology, and be patient.** The results of these initiatives will enable the industry to grow into one that provides high-quality, high-paying jobs to a large section of our citizens.

## **Purpose**

Throughout the United States, biotechnology is a growing field of research and industrial competition. Emerging as a possible forefront of the current technological revolution, biotechnology is gaining an ever-growing percentage of the technology investment in this country. Biotechnology promises to revolutionize the way in which we live, how our research dollars are spent, and the companies for which we work. If Tennessee is to become and remain competitive in this important field, it must understand what biotechnology research and industry currently exists in the state and determine the best plan for stimulating biotechnology growth in Tennessee.

The creation of the Tennessee Governor's Biotechnology Task Force in 2002 was an important step in this process. It was commissioned to study the current status of the biotechnology industry in Tennessee and make recommendations designed to promote the future development of the industry. In the 2002 "Report of the Governor's Task Force on Biotechnology", the Task Force recommended an inventorying of biotechnology companies in Tennessee. It also stated the need to identify biotech synergies and competencies to establish centers of excellence and biotechnology clusters.

The Tennessee Technology Development Corporation (TTDC) along with the Tennessee Biotechnology Association (TBA) and Science Applications International Corporation (SAIC) championed the 2002 Tennessee Biotechnology Assessment Survey, which was conducted as a first step to meeting these challenges. To gain a picture of the state of biotechnology in Tennessee, people involved in biotechnology, in both the public and private sectors, were polled to determine what work was being done in the field. Additionally, they were polled for their opinions about the state of biotechnology in Tennessee, their criticisms and plaudits for Tennessee in the biotechnology area, and other information that would be of assistance in fostering biotechnology in Tennessee. This report represents the results of that Survey.

## **Scope**

This report is a compilation and analysis of data collected during the Tennessee Biotechnology Assessment Survey. This Survey was conducted to gain information on the state of biotechnology in Tennessee for both the public and private sectors. Voluntary participants included individuals, companies, and institutions participating in a web Survey, a phone Survey, and face-to-face focus groups. Results of literature searches were also included. For this Survey, biotechnology-related research, development, and manufacturing were not limited to life sciences. Opinions were solicited from institutions and companies either supporting or related to biotechnology and included such researchers and companies as those involved in pharmaceutical development, bioinformatics, materials and services suppliers, venture capitalists, and business consultants assisting startup companies. This broad spectrum of companies, institutions, and interested individuals, representing both those working directly in biotechnology and those in related or supportive fields, form a "biotechnology community" all of whom have a stake in the future of biotechnology in Tennessee. Surveying the entire biotechnology community was important to developing as complete a picture as possible of the state of biotechnology in Tennessee and the factors affecting its growth.

The primary limiting factor for this Survey was its voluntary nature. No voluntary survey can be used to completely portray the state of biotechnology in Tennessee. However, with good response rates and appropriate interested participation, a strong picture of the state of biotechnology in Tennessee can be developed as well as provide indications of synergies, gaps in biotechnology services and development, and trends in growth.

## **Approach**

With any research, the strength of the conclusions that can be drawn is directly proportional to the depth and breadth of the study. This principle led the TTDC to choose to develop information on the state of biotechnology in Tennessee through four different, but related, techniques. The TTDC instituted a web-based Survey placed on their website and requested both commercial organizations and individual researchers to respond. External sources, as well as the existing Tennessee Biotechnology Association database, were used to produce a list of companies and researchers for the Survey. The web Survey divided respondents into two categories: (1) academic/institutional respondents primarily from universities and (2) research hospitals and commercial respondents. These two categories of respondents were each given a similar but different Survey. The questions in the Survey were designed to elicit opinions concerning such information as:

- the importance of various factors to biotechnology in Tennessee
- the availability of those same factors to biotechnology in Tennessee
- the focus of ongoing business or institutional research, biotechnology, or biotechnology-related products or services offered
- their sense of the biotechnology market in Tennessee
- the reasons the company is located here

To determine the effectiveness of the web Survey, a phone Survey was also conducted to gain a general assessment of the numbers and a business focus of the companies that did not respond to the web Survey but who have biotechnology-related products or services. By conducting the phone Survey, SAIC could better understand the depth of the representation of the web Survey response and the interest of biotechnology-related companies in completing the web Survey. The phone Survey also allowed selected information to be added to the web Survey thereby building a more complete picture of the commercial aspect of biotechnology in Tennessee.

To complete the picture of the state of biotechnology in Tennessee, four focus group meetings were held across the state. These meetings were held in Johnson City, Oak Ridge, Memphis, and Nashville, and they brought together some of the key commercial and institutional players in biotechnology and related fields as well as organizations interested in promoting biotechnology in Tennessee. These focus groups facilitated roundtable discussions of the preliminary results of the web Survey and supported a more detailed development of opinions of these key players on important issues such as the identification of areas of weakness in Tennessee for biotechnology development and possible actions necessary to strengthen those areas.

Finally, to place the results of the Survey in perspective and to examine the results of the implementation of strategies for biotechnology in other states, current literature was examined. The rise of biotechnology and biotechnology-related research and industries has prompted many

state and regional organizations to study the phenomenon of biotechnology growth and how they can capitalize on and promote it. These studies provide a unique basis to compare what has been learned about biotechnology in Tennessee to what has been discovered elsewhere, which may help clarify the future role of biotechnology in the state of Tennessee.

## **Success of the Survey**

The initial web-based Survey was placed on the TTDC website and made available to anyone interested. 737 notifications were mailed to individuals and companies, primarily those in research and development or involved in biotechnology businesses that were on the rolls of the TBA (some were obtained from other information sources) and considered to be likely candidates for completing the Survey. The Survey was presented in two forms: one aimed primarily at institutions and one aimed primarily at businesses. For the business-directed Survey, there were 54 respondents from 49 companies (from a total mailing to 288 corporate individuals from a wide range of businesses). For the institution-directed Survey, there were 100 respondents representing 19 institutions (from a total mailing to 449 individuals associated with institutions). Combined, these 154 responses constitute a better than 20% response rate. In subsequent phone Surveys, 175 companies (chosen from the original 288 companies) were approached. Of the 175, 79 responded with the requested information, which represents a response rate of more than 45%.

These numbers represent a strong response to the Survey. It suggests that the audience was well targeted, and that the subject of the Survey was of interest to the respondents. In addition, over 35 individuals participated in the four focus groups, demonstrating the interest of the biotechnology community leaders in participating in the Survey. Further, numerous individuals, who head research groups at Tennessee institutions and who are involved in moving intellectual property from the institutions to the commercial sector, have been contacted directly for detailed responses to specific questions. Their response has been near 100%.

Overall, both statistically and anecdotally, the Survey has been well received and has enjoyed excellent support throughout the biotechnology community in Tennessee.

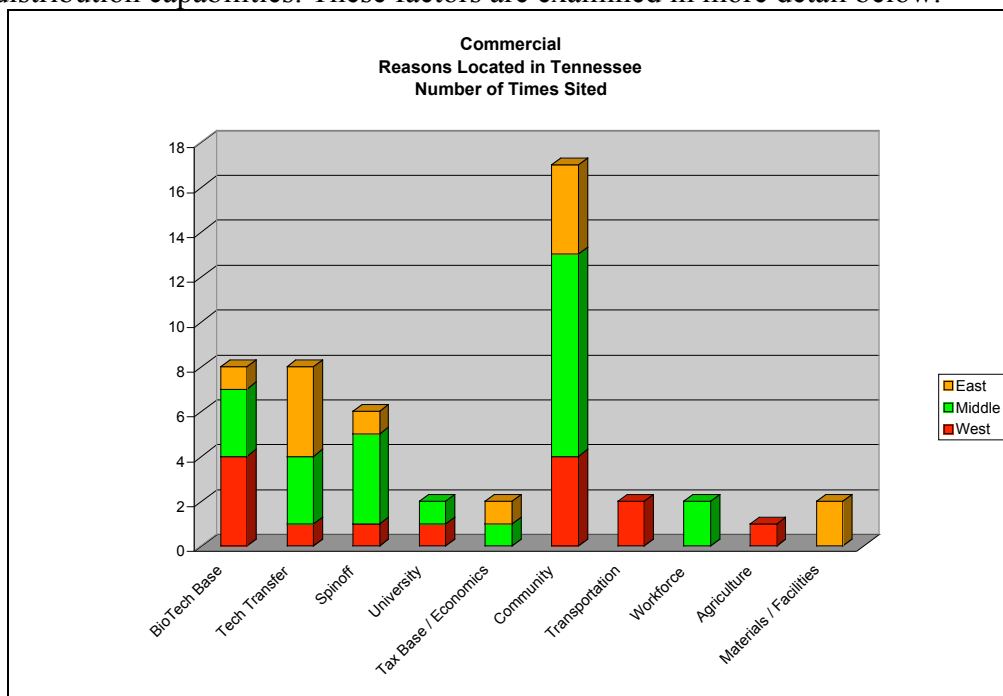
## **Strengths**

Many of the Survey questions were designed to derive not only the reasons that companies are located in Tennessee but also their perceptions of the state's strengths. This data was combined with the results of other recent assessments to provide SAIC with a picture of how Tennessee's resources compare to other areas. The other assessments that were used include:

- a study of Biotechnology done by the Brookings Institute of biotechnology in the top 100 metropolitan areas of the United States<sup>1</sup>
- studies done by the Battelle Memorial Institute of biotechnology in the cities of Memphis, TN<sup>2</sup>, and Pittsburgh, PA<sup>3</sup>, and in the state of Arizona<sup>4</sup>
- a study done by the Boston Consulting Group of biotechnology in the state of Massachusetts<sup>5</sup>
- a study done by Monroe Consulting of biotechnology in the East Bay Area of San Francisco, CA<sup>6</sup>
- a study done by Ernst and Young of the economic impact of biotechnology to the United States<sup>7</sup>

Note that these assessments are internally consistent but, due to the variance in definition of terms such as ‘biotechnology’, cannot always be compared accurately to each other. The data elements from these assessments should, therefore, only be compared within an assessment and not compared to data outside their source.

Tennessee Biotechnology Assessment Survey data was analyzed in the larger context provided by these other reports. In this way, SAIC was able to see which of Tennessee’s attributes represent real strengths that can be capitalized on to attract and grow our biotechnology industry. Figure 1 lists the factors that respondents indicated were the reasons their businesses were located in Tennessee. The strongest factor is that they were a spin-off from a local institution; however, other factors emerge from the data as well. The data shows that two factors represent Tennessee’s greatest strengths in attracting and retaining biotechnology companies: quality of life and distribution capabilities. These factors are examined in more detail below.



**Figure 1: Reasons Businesses Are Located in Tennessee**

### Quality of Life

Quality of life is a somewhat intangible notion. It means different things to different people, but generally comprises a number of factors such as beauty of the environment, low cost of living, access to services, and a lack of such problems as crime, traffic congestion, and pollution. Tennessee certainly possesses all of these; however, cost of living in particular may be a strength that can be used to our advantage.

In a recent study done for the East Bay Area of San Francisco, CA<sup>6</sup>, (just outside San Francisco’s premier biotech hub located on the peninsula) local biotech companies were asked, “*Why did your company choose to locate or relocate here?*” The most common responses were a) lower space costs/land values and b) housing choices/costs. When asked, “*What do you consider to be the principle barriers to your company’s growth?*,” answers were a) cost of living

(overwhelmingly ranked # 1) and b) high space costs. Data from the Massachusetts study<sup>5</sup> shows similar feelings. **Since land/space costs in Tennessee are far lower than those in either San Francisco or Boston, this may represent an opportunity for Tennessee to lure some of these companies here.**

### **Cost Considerations**

Other studies<sup>5,6</sup> have shown that biotechnology companies strongly prefer to have their manufacturing operations as close as possible to their research and development (R&D) centers. Cost considerations such as land, construction, taxes, utilities, and labor can become a major factor in determining the location of production and distribution facilities. As biotechnology companies transition from the testing and approval stages to production, distribution, and marketing, the high costs of operating in areas such as San Francisco, CA, and Boston, MA, compared to Tennessee could become a significant advantage. It is interesting to note that the siting of three of the largest biotechs in the San Francisco East Bay Area (Genentech, Chiron, and ALZA) was the direct result of a plethora of incentives given by Federal, state, county, and city agencies<sup>5</sup>. Without these incentives, it is unlikely that the companies would have found it cost effective to locate there.

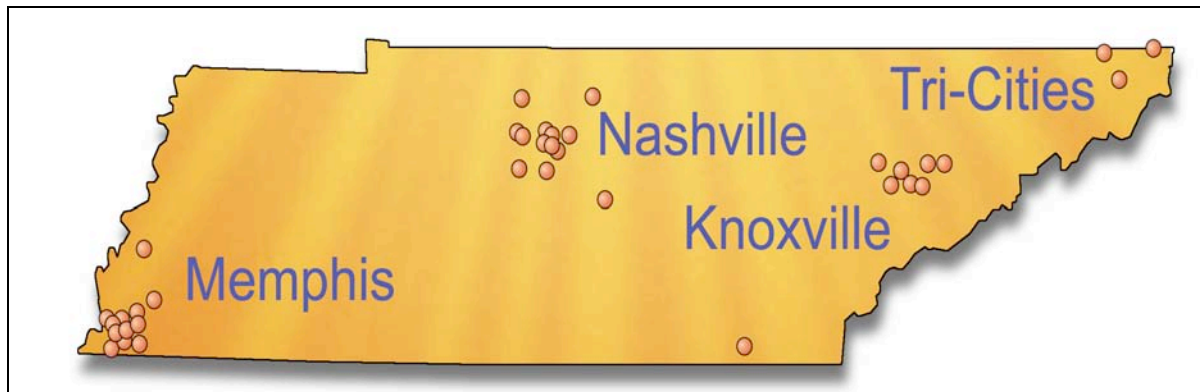
While cost considerations are important for the siting and success of biotechnology manufacturing plants, R&D facilities and start-ups are not as strongly motivated by these factors. Primary factors contributing to the regional development of biotechnology companies is proximity to major research universities and venture capital. These companies are focused almost entirely on R&D and consider the traditional economic development incentives to be of relatively low value. These incentives include items such as tax breaks, cost of space, local regulation, and wage rates. The availability of scientists and a nearby research university are extremely important for start-up companies. The availability of venture capital in the region is also extremely important since venture capitalists prefer to invest in companies that are nearby. Proximity makes it much easier for them to provide oversight of their investments<sup>7</sup>. High-caliber research institutions in Tennessee clearly account for the clusters of start-ups that currently exist and are certainly a positive factor when trying to grow these clusters. They are, however, somewhat hampered by the almost complete lack of local venture capital.

**It may be prudent for Tennessee to focus on later-stage companies in addition to increasing the number of start-ups by improving the availability of venture capital resources.** This strategy will be more likely to better mesh with the makeup of the state's manufacturing-oriented workforce.

### **Clusters**

A recent analysis of biotech jobs in the East Bay Area of San Francisco, CA<sup>5</sup>, reveals a distinct pattern of clusters. Alameda County has the majority of the region's biotechnology firms and jobs. This is due to the County's proximity to research universities as well as its relatively affordable industrial and residential space. Research institutions in this area include The University of California (UC) Berkeley, UC San Francisco, Stanford University, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Sandia National Laboratory, Western Human Genome Project, National Aeronautic and Space Administration (NASA) Ames, the U.S. Department of Agriculture's Plant Genome Center, and the California Institute for Bioengineering and Quantitative Biomedical research (QB3). Other biotech centers show this same pattern of cluster formation.

A similar pattern can be seen developing in Tennessee where new companies tend to cluster around large research institutions (see Figure 2). These institutions include Vanderbilt University, the University of Tennessee Health Science Center, and Oak Ridge National Laboratory among others. These clusters are clearly visible in the illustration below.



**Figure 2: Tennessee Clusters**

Survey data shows the beginnings of four clusters forming in Tennessee: Memphis, Nashville, and to a lesser extent Knoxville, and the Tri-Cities area. The proximity to major research institutions in these clusters is obvious. Data indicates that the companies and researchers in these clusters have a variety of business focuses. Two areas seem to be leading the rest: diagnostics/therapeutics and medical devices. This is most likely due to the strong health care industry found in both Memphis and Nashville. None of these clusters is large enough to be self-sustaining. For these clusters to grow, several outside factors will need to be present. Because of this, these clusters cannot yet be counted among Tennessee's strengths.

The future of these clusters could be very bright indeed if they are properly nurtured. Standard & Poor's reports that the medical device and products industry generated worldwide sales of about \$165 billion in 2000. *U.S. Industry & Trade Outlook for 2000*, prepared by the U.S. Commerce Department, projects 5-8% annual growth through 2006 for this industry. Major growth is projected in specific, new medical technology products, such as lasers (15%), cardiovascular devices (12.4%), minimally invasive surgery (8.9%), and wound care products (12%).

### **Distribution Capabilities**

Another strength that was noted in the Survey, and can easily be capitalized, was Tennessee's centralized location and excellent distribution infrastructure. This infrastructure is crowned by Federal Express in Memphis which serves as the major distribution service utilized by several Surveyed firms. This strength has been described as "bio-logistics" and promises to play a much larger role in the future as more companies move from R&D into processing of biological materials such as proteins. Manufacturing of these materials is very different from the manufacturing done by pharmaceutical companies in the past. These materials can require specialized handling and have very short shelf lives that require unique distribution capabilities.

Medical diagnostics is another area that requires excellent logistics. Some of the new diagnostic techniques being explored have a very short time span in which the samples must be processed. For example, laser cytometry counts the types of specific cells present in a sample. Since the cells must still be living for the technique to be accurate, the sample must be processed within 12

hours of being collected. Having a facility that is centrally located and served by a carrier, such as Federal Express, is mandatory for these techniques to be commercially viable.

### **Success of Collaboration and Intellectual Property Transfer**

Intellectual property transfer to the private sector is one of the key activities that will increase the depth and breadth of biotechnology in Tennessee. Numerous intellectual property (IP) transfer efforts are ongoing. The UTRC, with offices at both the Knoxville and Memphis campuses, has had great success in IP transfer in biotechnology and biotechnology-related fields. Some of the primary successes through the Knoxville office include the bioluminescent bioreporter integrated circuit (BBIC) and plasma processing for sterilization. The BBIC is an electronic, biological-chemical device that combines a genetically constructed bioreporter that emits light under specific biological conditions packaged with an electronic circuit capable of detecting the light and processing and reporting a signal. This technology is partially co-owned by the University of Tennessee (UT) with Oak Ridge National Laboratory (ORNL), and a number of government and industrial partners are involved in development and commercialization. Plasma processing for sterilization is applied to surfaces and airstreams and currently involves the successful commercialization of advanced plasma-based devices for sterilization and filtering of bio-contaminants by a local company.

At UT Health Science Center – Memphis, through the UTRC, there have been IP transfer and commercialization successes that include cancer therapy and cancer diagnostics for prostate, breast, and ovarian cancer. Pharmaceuticals for treating prostate and brain cancer are also being commercialized. Other pharmaceuticals that have made it to the private sector include partner drugs for acquired immune deficiency syndrome (AIDS) remediation, particularly for remediation of AIDS wasting. New techniques and tools are being developed and commercialized in the areas of vascular biology and blood platelet analysis. New imaging systems are being developed and improvements to MRI, X-ray, and variable resolution imaging are being made.

There are also numerous IPs under development targeted for future technology transfer. These include such research as:

- efficient detection of individually labeled molecules that interact with a polymerase enzyme
- assay for monitoring protein aggregation reactions
- nano-scale structures that have delivery, sensing, or processing capability for biomaterials
- markers for dangerous biomaterials that could endanger food supplies
- an enhanced bio-trap for well-monitoring

Vanderbilt University Medical Center (VUMC) has had a number of successful IP transfers including the glaucoma drug Trusopt and the pest control system Sentricon. In addition, IP for water-soluble nanotechnology for drug, gene, and antigen delivery and vascularization has been successfully transferred to a startup company supported by the Cumberland Emerging Technologies (CET) incubator, a cooperative venture between Cumberland Pharmaceuticals, the TTDC, and Vanderbilt University. CET supplies the infrastructure required by researchers to transition their IP into startup companies. It also assists in leveraging the assets of Federal funding including the Small Business Innovation Research and Small Business Technology Transfer programs for startups.

Collaborative efforts within Tennessee are, like IP transfer, a cornerstone for the advancement of biotechnology in the state. An example of statewide collaborative efforts is the Tennessee Mouse Genome Consortium (TMGC). The TMGC is a collaborative effort of East Tennessee State University, Meharry Medical College, ORNL, St. Jude Children's Research Hospital, the University of Memphis, the UT Health Science Center in Memphis, UT – Knoxville (UTK), and Vanderbilt University. TMGC facilitates biomedical research by bringing together experts in mouse genetics, basic biomedical research, clinical research, laboratory animal care, bioinformatics, bioanalytical technologies, and research administration. Other collaborations include efforts between UTK and ORNL to build faster software for effective analysis of gene expression data and efforts between the UT Health Science Center and private industry to create a line of biodegradable implants, a pharmaceutical-laced, biodegradable gel with veterinary applications.

To take the UT system to the next level in IP transfer and research collaboration, the UTRF has been developed as a successor to the UTRC. As the UTRF comes to fruition, it will provide UT's researchers with important IP management. It will also provide necessary incubator facilities as well as develop partnerships and alliances with the business community and state and Federal agencies. It will provide all future collaborative efforts involving the UT system with a means to build on previous successes. UTRF is an important component in any plan to advance biotechnology within the state of Tennessee.

### **Summary of Strengths**

Tennessee has some of the necessary resources to grow biotechnology within the state into an industry employing large numbers of people in high-paying occupations. Its quality of life, low cost of living, and centralized location make Tennessee an excellent choice for companies transitioning to manufacturing and distribution. The seeds of growth are there in our presence in Diagnostics/Therapeutics and Medical Devices. Our preexisting successes with collaboration and intellectual property transfer demonstrate that Tennessee has the intellectual resources for future startups. These areas show great promise for the future if they are carefully nurtured.

### **Gaps in Key Areas**

Survey respondents were asked to name items (in a free-text field) that they felt were lacking in Tennessee and that hampered their growth (see Figure 3). Respondents were also asked to rate the availability and relative importance of several items important to growth. In both of these areas, the items that respondents cited most often as lacking in Tennessee and very important were: access to a skilled workforce, access to capital, and public policy (tax incentives, etc.).

---

## What factors are limiting your growth?

Start-ups	Mature companies
1. Lack of capital	1. Lack of skilled workforce
2. Lack of skilled workforce	2. Public policy
3. Public policy	3. Lack of capital

---

**Figure 3: Growth Gap Items**

These same three items were chosen both by representatives of startup companies and mature companies alike, although in a different order. Startup companies listed capital first followed by workforce and policy. Mature companies (as measured by revenue) were more likely to select inadequate workforce first followed by policy and capital. Other responses given were items such as good technology transfer and access to specialized facilities. These items were selected far less often than those discussed above.

### **Inadequate Workforce**

According to the Corporation for Economic Development's "Development Report Card for the States" (DRC) 2002 rankings, Tennessee has several severe problems in the area of education. Tennessee ranks 48<sup>th</sup> in the nation in high school graduation rates, 48<sup>th</sup> in students achieving even some high school education, 40<sup>th</sup> in K-12 expenditures, and 39<sup>th</sup> in the number of science and engineering university graduates. Tennessee does not rank in the top half of the states in any measurement related to education.

Our existing workforce does not fare much better. Tennessee ranks 32<sup>nd</sup> in the number of Ph.D. scientists and 42<sup>nd</sup> in the number of high-technology jobs. Overall, Tennessee received an "F" rating for our human resources by the DRC. An inadequate workforce represents an enormous barrier to the growth of biotechnology in the state. Without addressing workforce issues, Tennessee cannot hope to compete for a share of the industry.

This does not mean that Tennessee should focus its efforts solely at the university level in order to produce more scientists. As discussed above, companies in the early phases of research and development are extremely unlikely to relocate. The point at which they will relocate is when they transition to manufacturing and distribution. Table 1, based on data from the East Bay Study, lists the differences in the makeup of companies at these two stages.

**Table 1: Percent of Workforce by Occupation**

<b>Occupation</b>	<b>Biotech Startup Companies</b>	<b>Mature Drug Manufacturing Companies</b>
Management	12.4%	12.3%
Professional	0.0%	12.1%
Scientific/Technical	43.2%	9.6%
Marketing/Sales	4.9%	2.2%
Clerical/Administrative	17.8%	10.1%
Service	2.1%	2.0%
Production Workers	19.5%	51.4%
Other	0.3%	0.3%

Table 1 shows a clear shift from “Scientific/Technical” to “Production” as the company matures. In the East Bay study<sup>6</sup>, biotech companies Human Resources Directors were polled to determine the types of personnel being sought. Production workers needed by the more mature companies generally do not require four-year degrees. AA/AS degrees from a community college, or even a high school diploma, are frequently enough for an entry-level position. This does not mean that any high school graduate is prepared to step into a biotech-manufacturing job. The Human Resource Directors emphasized the importance of acquiring math, science, computer, and communications skills for jobs in the biotechnology industry. Individuals with a high school diploma and general education that have not taken any science courses lack the basic skill set to enter the biotechnology industry.

One notable plan to address the shortage of skilled workers is the creation of a Memphis charter school, sponsored by the Memphis Biotech Foundation. The recently approved Memphis Academy of Science and Engineering (MASE), a grades 7-12 school, will be Tennessee's first charter school. The Biotech Foundation's MASE will have students in class for a longer school day and a longer school year, focusing on real-world applications of science, technology, and engineering and pairing kids with researchers in the university or private sector. This type of initiative demonstrates what is needed to prepare Tennessee’s workforce for the industry.

Investments in education to create a pool of workers for biotech production should pay great dividends in terms of taxes and other benefits for the state. Figure 4 lists average employee earnings for different occupations.

Average Employee Earnings (2001)	
Drugs	\$89,608
Organic Chemicals	70,273
Agricultural Chemicals	61,423
Aerospace	60,300
Industrial Machinery	56,800
Motor Vehicles	56,500
Medical Devices	52,957
Metals	41,300
Construction	37,600
Rubber and Plastics	36,100
Hospitals and Laboratories	36,000
Tennessee (all workers)	31,491
Hospitality and Recreation	21,500
Source: U.S Bureau of Labor and Statistics	

**Figure 4: Average Employee Earnings by Occupation**

In 2001, according to the U.S Bureau of Labor Statistics, the average worker in Tennessee earned \$31,491, well below the numbers shown for life sciences employees. Past studies have shown that dollars invested in workforce education provide better than a 3-to-1 payback to the local economy. With the high pay scales and expected growth in biotech, Tennessee could see an even higher rate of return.

### **Access to Capital**

The second crucial gap noted in the Survey was access to capital to expand business operations. Every study referenced in this document found that the presence of a strong venture capital base was an essential ingredient to growth in biotechnology. In fact, the necessity for venture capital is so strongly correlated with success in this area that many studies listed it as the number one factor for success in the regional development of biotech<sup>1,2,3,4</sup>. This is certainly the case in San Francisco, CA, and Boston, MA, the top two biosciences clusters in the nation, that are also the top two regions for venture capital (see Figure 5). These two areas are home to 31 of the 51 active biotech venture capital firms in the nation<sup>1</sup>. To quote the Brookings Institute report, *“...Thus the nine leading biotechnology centers may account for a smaller share of NIH funding and patenting than they did two decades ago, but now they account for a larger share of new biotechnology businesses ...The critical factor in this process is the very high concentration of capital flows in biotech centers: the nine leading biotech regions account for 88 percent of all venture capital for biopharmaceuticals, 92 percent of the most active biotechnology venture capital firms, and 96 percent of the dollar value of research alliances with pharmaceutical firms.”*

Studies have shown that venture capital firms strongly prefer to invest in companies that are local to their offices<sup>7</sup>. This enables the venture firm to provide a higher level of oversight of their investment. In the post dot-com era, when venture capital firms are coming under far more

scrutiny by their investors, this oversight has become even more of an issue. As shown in Figure 6, Tennessee suffers from an almost complete lack of venture capital for the biosciences.

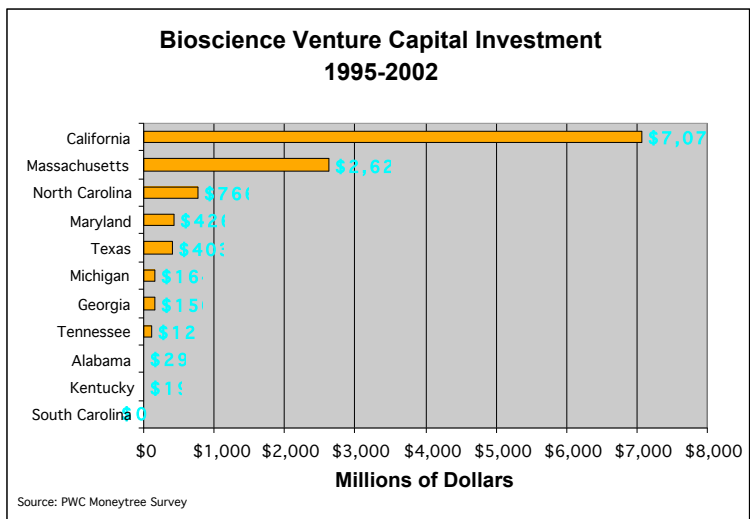


Figure 5: Venture Capital Investment in Biotech (selected states)

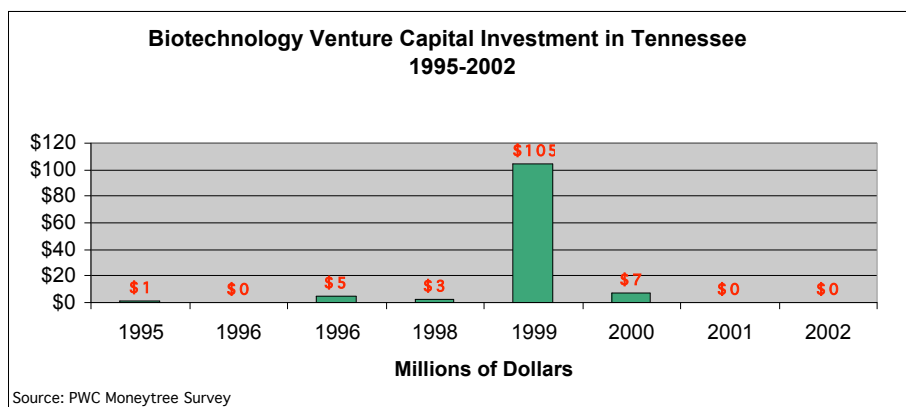


Figure 6: Venture Capital Investment in Biotech (Tennessee)

According to Ernst and Young<sup>7</sup>, the typical biotech firm spent \$8.4 million on research and development and earned revenues of just \$2.5 million in 1998. These firms are, therefore, heavily dependent on outside sources of capital for several years after their formation.

### Public Policy

Public policy in the form of tax incentives, a good regulatory climate, business incubators, and support for publicly funded research institutions is the third crucial gap noted by Survey respondents. Gaps in these areas of state infrastructure are the ones most likely to be attacked by other regions seeking to attract fledgling companies away from Tennessee. These gaps are also a detriment when trying to attract new companies.

Long lead times required to bring biotechnology products to market require highly supportive and stable tax and regulatory policies. These tax policies can provide additional capital for emerging companies, as well as ensure an even playing field between older, traditional industries

and emerging high-technology industries such as the biosciences. When Massachusetts recently began to realize that their dominance in biotechnology was starting to erode, they commissioned a study to determine the steps needed to restore it. The study<sup>5</sup>, released in December 2002, found that Massachusetts must take several, key public policy steps to maintain its position. These steps were titled “*Ten Things the Governor and the State Legislature Can Do Immediately*” and contain such measures as:

- Make a commitment to stabilize the tax environment, and create a permanent investment tax credit.
- Change the legal definition of an R&D corporation, and file appropriate legislation to ensure that all life-sciences start-ups can benefit from the status.
- Encourage state pension funds and other public investment funds to invest in start-ups and early-stage venture capital funds.
- Promote collaboration initiatives among public universities, public agencies, and the industry.

All of these policies would apply equally well in Tennessee. The economic development incentives provided to traditional heavy industries in Tennessee may not be appropriate for bioscience firms that require customized job training programs, partnerships with academic health centers and universities, and equity fund investments. The state must establish a specific set of policies tailored to the needs of high-technology biotech firms.

### **Summary of Gaps**

Our state has three significant gaps that are barriers to the growth of this industry: inadequate workforce, lack of venture capital, and poor public policy. It is clear from the Survey responses that these three items must be addressed to attract new biosciences firms and to nurture the growth of the existing clusters. It must be noted that several initiatives are already underway to close these gaps, such as the proposed Research Tax Credit.

### **Comparison to Other Clusters and States**

Biotechnology is on the minds of economic development agencies across the United States. 83% of local development agencies place biotechnology as one of their top two priorities<sup>7</sup>. Currently, there are 41 states that have active biotech programs. These states and regions pursuing biotechnology see it as the “next big thing” and don’t want to be left out when the growth begins. Examples of bioscience investments (*source: Battelle Memorial Institute*) include the following:

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

The national biotechnology industry has grown rapidly in recent years, doubling in size between 1993 and 1999. The biotechnology industry generated \$10 billion in tax revenues in 1999, including \$6.8 billion in federal taxes, \$1.9 billion in state taxes, and \$1.2 billion in local taxes<sup>7</sup>. This level of growth is expected to continue for several more years as the seeds of the genomic revolution begin to bear fruit. With this large of a potential payoff, it is insightful to compare Tennessee to its competitors at the state and regional levels.

## Other Clusters

Table 2 through Table 4 compare Tennessee's two largest bioscience clusters with the current national leader, Boston, MA, and with the average numbers for the nine largest clusters in the nation. In each case, the data represents the Metropolitan Surrounding Area (MSA), not just the individual cities.

**Table 2: Metropolitan Surrounding Area (MSA) Funding**

MSA	2000 NIH Funding	% of Total NIH Funding
Memphis	\$78,984,525	0.7%
Nashville	\$140,546,951	1.2%
Boston	\$1,422,875,474	12.2%
Average of 9	\$812,000,000	7.0%

**Table 3: Number of Biotechnology-related Patents Granted (1975 – 1999)**

MSA	Number of Patents
Memphis	279
Nashville	83
Boston	3725
Average of 9	2641

**Table 4: Venture Capital Investments in Biotech (1995 – 2001)**

MSA	Number of Investments	Value	Percentage of Total for Nation
Memphis	0	-	0.0%
Nashville	4	\$11,520,000	0.1%
Boston	211	\$1,915,654,300	19.7%
Average of 9	101	\$957,000,000	9.8%

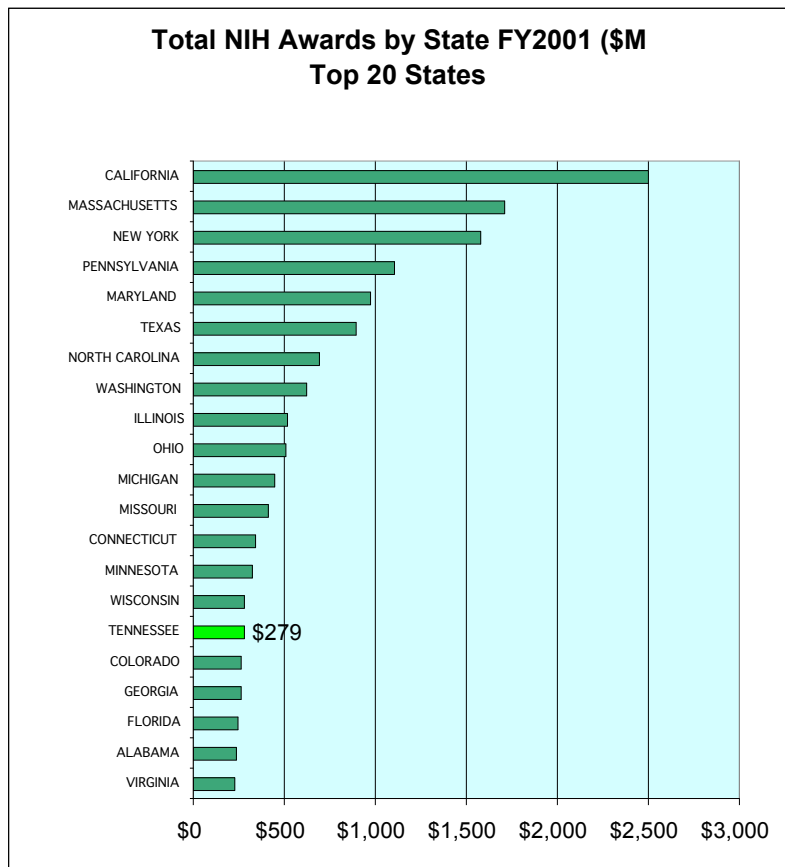
Source: Brookings report<sup>1</sup>

The top nine MSAs accounted for almost 90% of the venture capital activity in the nation for the past 15 years. It is clear from this data that Tennessee's clusters have a very long way to go to reach the top tier. (Note that for purposes of comparison the Brookings report used a fairly narrow definition of "Biotechnology-related" for determining patent numbers. Vanderbilt University alone has far more than 83 patents in the life science technologies overall. And both the number and percentage of patents in life sciences have been growing since 1999, the end of the period over which the patents were examined. But while we, Tennessee, have been growing in life science patents, so have other biotechnology markets.)

## Other States

41 of the 50 states have active biotech programs. Examining the programs in a few of these states gives a clearer picture of what Tennessee must do to compete for a share of the biotech growth. The amount of NIH funding has historically been a strong indicator of growth in the biosciences, though this has shifted somewhat in the last two years, as the amount of venture capital funding has become a stronger factor. Figure 7 shows the total NIH awards for several states. Tennessee ranks well below the leaders in this criterion, though it has improved in recent years and is

currently ahead of several neighboring states. It should also be noted here that a survey of the four largest research institutions in Tennessee, The University of Tennessee, Vanderbilt University, Oak Ridge National Laboratory and St. Jude Children’s Hospital showed that over \$580 million in external funding (both NIH and non-NIH) was available for biotech and biotech-related research. This is an encouraging result but Tennessee needs to build on this to compete for a share of the biotech growth.



**Figure 7: NIH Awards**

For a state to develop a significant presence in biotechnology, that state must make a concerted, long-term commitment. Biosciences companies typically require many years before they become profitable and must have a stable, supportive environment during this time. States that began to invest in biotechnology several years ago are now beginning to reap the rewards. A description of two of these states, Georgia and Maryland, and their programs is provided below.

**Georgia**

Beginning in 1991, the state of Georgia invested \$312 million into programs through the Georgia Research Alliance (GRA). These funds have been used to construct top-tier research facilities and laboratories and to attract key researchers to Georgia universities. The bulk of these funds have been invested to develop the bioscience sector. During the last 10 years, R&D expenditures in Georgia have doubled, increasing from \$400 million annually to more than \$800 million. Total bioscience research in Georgia jumped by \$96 million since 1995, reaching \$430 million.

Total NIH awards for the state almost doubled between FY 1997 and 2000. Most of this increase is directly attributable to GRA investments.

### **Maryland**

Maryland, like Tennessee, began their biotechnology initiative without any significant bioscience infrastructure or the presence of a venture investment community. In 1991, Maryland embarked on a strategic plan that specifically addressed key items such as:

- Venture capital
- Business incubation
- Workforce development
- Tax and regulatory issues

At the start of this plan, Maryland had 53 biotechnology companies employing 3,627 people. By 2001, Maryland had 258 companies with total employment of almost 16,000. This long-term, comprehensive plan produced results that have made a significant contribution to Maryland's tax base and placed them among the top states in this industry.

### **Summary of Comparisons**

Other states have paved the way for Tennessee and prepared a roadmap that it can follow to grow its biotechnology industry. Clearly, Tennessee needs a long-term plan to achieve this goal, as the payoffs will not come for 10 years or more. A large and vital biotech industry can be developed if we see the plan through.

## **Conclusions/Recommendations**

### **Tennessee's Strengths and Weaknesses Summarized**

Now that the initial Survey is complete, there is a baseline, method, and format for the data. Tennessee has clusters of biotechnology that are beginning to form. Tennessee's strengths are quality of life and distribution capabilities while its weaknesses are the skills of the workforce, the lack of venture capital, and public policy. However, this is a snapshot in time. It will be important to continue measuring the biotechnology presence in Tennessee on a regular basis to keep abreast of growth and trends. In particular, major issues that are hampering existing firms from expanding and new firms locating here must be monitored. The Survey needs to be refined to focus in more detail on the specific issues that affect biotechnology in Tennessee, followed by a re-Survey of companies and institutions to measure the results of initiatives that are undertaken.

### **Recommendations**

Studies have shown that R&D startups do not move far from the institutions that spawn them<sup>6</sup>; however, they will move when transitioning to manufacturing and distribution. **With our low costs and excellent distribution, Tennessee may be able to attract these firms to locate manufacturing facilities here.** One strategy for Tennessee may be to promote the development of pilot manufacturing plants and contract manufacturing facilities (bio-processing, fermentation, and cell culture). Both the lack of investment capital and public policy support make it very difficult for small companies to build these types of manufacturing facilities themselves, and their presence here could be a strong discriminator.

To close the gaps delineated this report, Tennessee needs to take action. The Survey clearly shows that actions to address the workforce and investment capital issue are sorely needed to nurture our biotechnology industry. The Governor's Taskforce on Biotechnology has made

numerous suggestions that will help to address these issues. In addition, agencies, such as the Tennessee Biotechnology Association, can be a powerful force in promoting networking among our companies and researchers, but without support from public officials, they cannot affect the kinds of changes Tennessee needs.

Once these changes are made, a metrics plan should be established to monitor their effectiveness. The data should be updated yearly to spot emerging clusters and trends. In addition, further research should be undertaken to address such specific questions as:

- How can we attract maturing biotechs to locate manufacturing and distribution facilities here?
- What public policy improvements can be made to assist new and growing companies?
- What training programs will enable our workforce to succeed in these companies?
- How can we help scientists collaborate/commercialize?

One lesson learned from every successful technology region studied is that success takes time. Developing a thriving biotechnology industry cannot be accomplished in a year or two; it requires a long-term effort measured in a decade or more. Tennessee needs to make this long-term commitment now, provide a stable and supportive environment, and be patient. The results of these initiatives will enable the industry to grow into one that provides high-quality, high-paying jobs to a large section of our citizens. Other states and regions, that were once behind in the biosciences, have successfully repositioned themselves as a leading region or have carved out a market niche for the future. Tennessee can do the same.

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## Appendix A

### Key Results from Data Analysis – Commercial

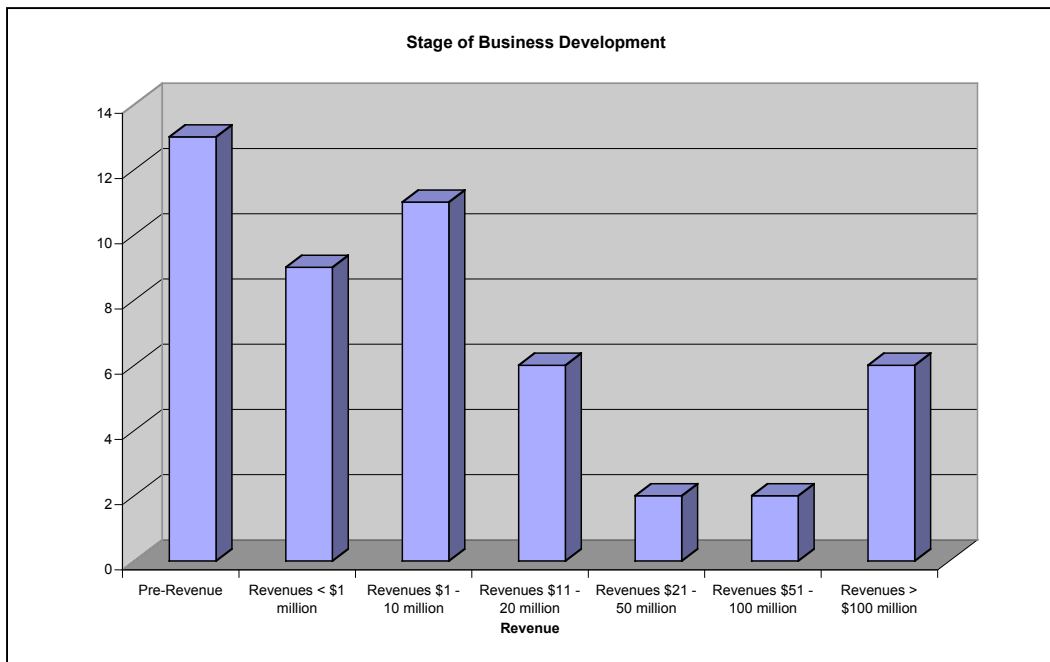
Analysis of Survey data resulted in some interesting or “key” results for the commercial sector. Results in several areas appear to have a strong impact on work going forward to build a stronger biotechnology base in Tennessee—these areas are presented in the following sections:

- Stage of Business Development
- Commercial Business Focus
- Relationships
- Reasons Located in Tennessee
- Market Growth
- Tennessee Constraints
- Commercial Employment in Tennessee

#### **Stage of Business Development**

Commercial respondents were asked to specify their stage of business development from the following list:

- Pre-Revenue
- Revenues < \$1 million
- Revenues \$1 – 10 million
- Revenues \$11 – 20 million
- Revenues \$21 – 50 million
- Revenues \$51 – 100 million
- Revenues > \$100 million.



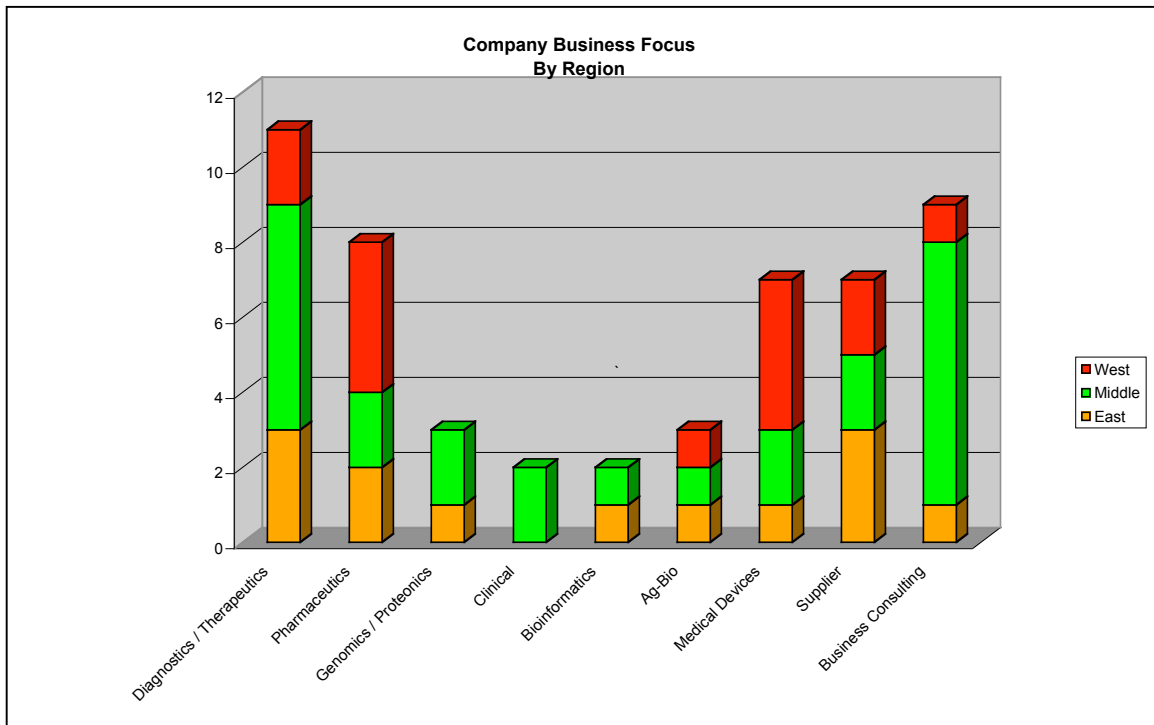
**Figure 8: Stage of Business Development**

13 companies stated they were at a level of startup they considered to be pre-revenue. 9 had revenues of less than \$1 million. 11 were in the \$1 – 10 million range. 49 companies responded to this question. Approximately 67% of those that were producing revenues fell below \$10 million or ‘small’. 27% were still in a startup phase.

**Commercial Business Focus**

Commercial respondents were asked to describe their business focus by either selecting a choice from a list or describing their product or service in text. Discussions and selections provided by 49 respondents were analyzed, grouped into East, Middle, and West Tennessee, and placed into 10 categories:

1. Diagnostics/Therapeutics
2. Pharmaceuticals
3. Genomics/Proteomics
4. Clinical
5. Bioinformatics
6. Ag-Bio
7. Forensic Toxicology
8. Medical Devices
9. Suppliers
10. Business Consulting.



**Figure 9: Company Business Focus By Region**

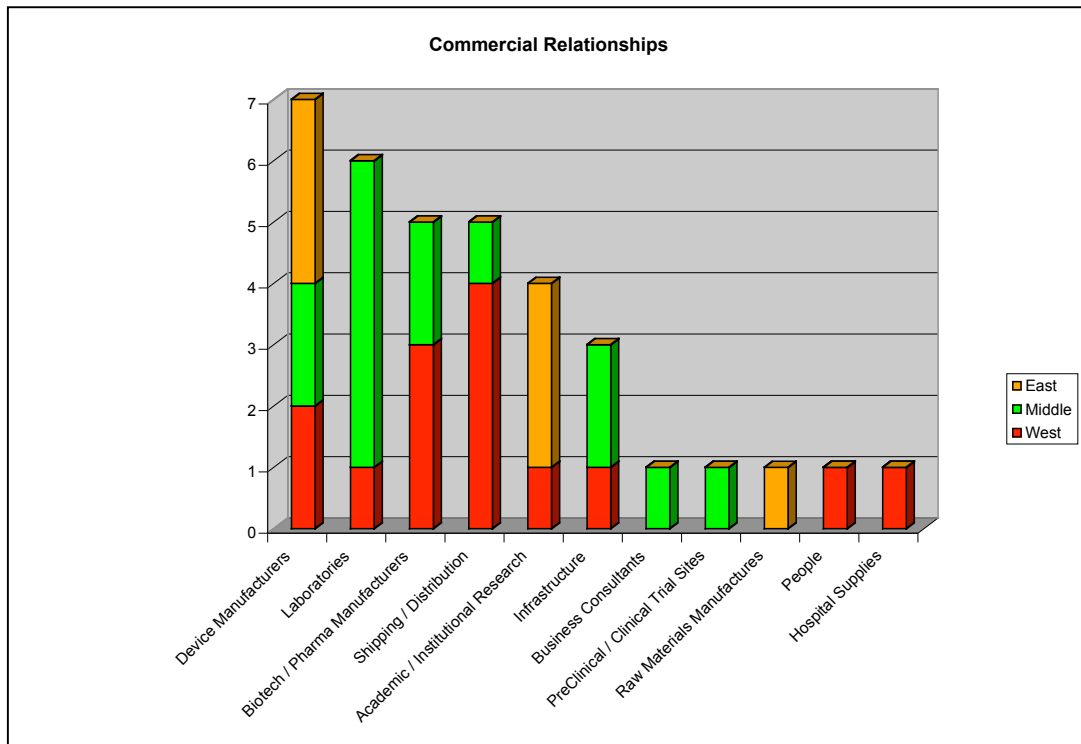
Based on the responses, companies who claim a business focus of diagnostics/therapeutics seemed to exist in all three regions of Tennessee with a total response of 11 companies. Pharmaceuticals followed a similar pattern with a total response of 8. No companies focused on genomics/proteomics responded from West Tennessee with a total response of 3 companies. Two

clinical trial firms from Middle Tennessee were the only ones to respond. An interesting result is that 7 firms specializing in business consulting (financial and business startup) responded from Middle Tennessee. Middle Tennessee had the largest commercial response, as could be expected from its large population and general business base. It would also be interesting to conjecture, however, the possible impact of the larger group of business consultants actively involved in biotechnology companies on the larger number and diversification of types of biotechnology companies in Middle Tennessee. The availability of this assistance could be an important synergy in the area.

**Relationships**

Commercial respondents were asked for a free-form list of their strategic suppliers to establish their relationships with other companies in Tennessee. The responses were examined, and 11 categories were established:

1. Device Manufactures
2. Laboratories
3. Biotech/Pharma Manufacturers
4. Shipping/Distribution
5. Academic/Institutional Research
6. Infrastructure
7. Business Consultants
8. PreClinical/Clinical Trial Sites
9. Raw Materials Manufactures
10. People
11. Hospital Supplies.



**Figure 10: Commercial Relationships**

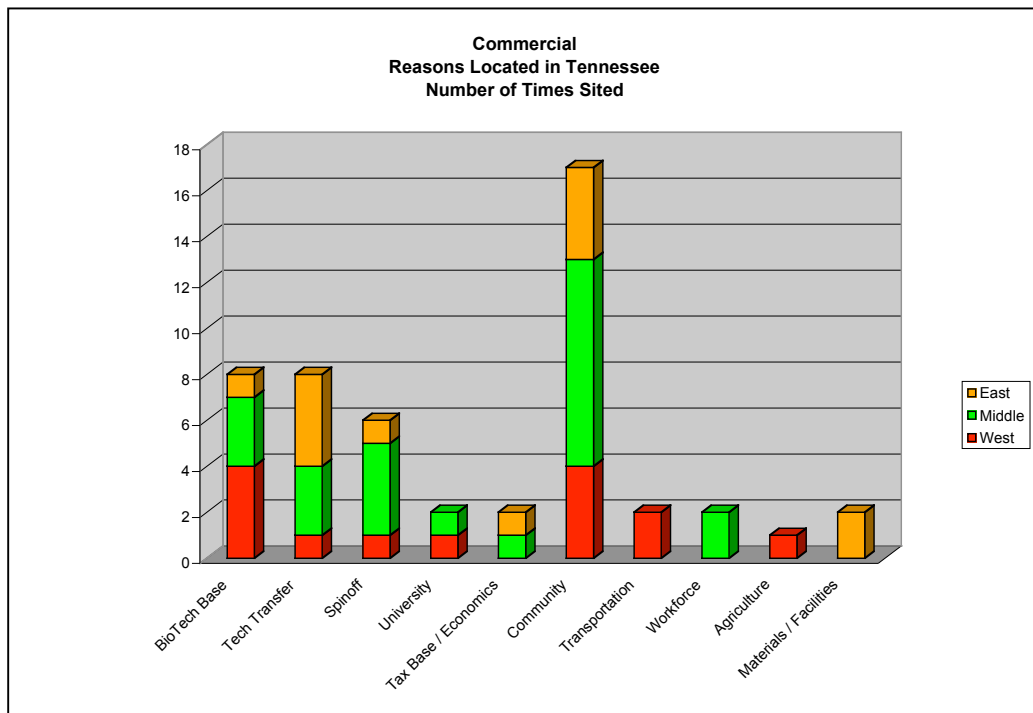
26 companies provided information. Each company's response could have resulted in multiple categories being cited, however, and a total of 35 responses were recorded.

The most cited category was device manufacturers with seven. These were spread relatively evenly across the three regions. Six companies cited relationships with laboratories and five of these were in Middle Tennessee. Relationships with other Biotech/Pharma Manufacturers were cited by five companies, as were relationships with Shipping/Distribution suppliers. Academic/Institutional Research organizations were cited four times and Infrastructure entities (other non-biotech/general business entities) were cited three times. Other unique relationships were cited only one time each.

**Reasons Located in Tennessee**

Commercial respondents were asked to state why their company was located in Tennessee. As each respondent could provide multiple reasons, each reason cited was given equal weight rather than each person. The discussions provided by the respondents were analyzed, grouped into three geographic regions (East, Middle and West Tennessee), and placed into 10 categories:

- |   |  |
|---|--|
| 1. Existing biotech base                                | 6. Community-related issues (quality of life, family, local schools, etc.) |
| 2. Technology transfer from a university or institution | 7. Availability of transportation  |
| 3. Spin-off from another company                        | 8. Availability of a skilled workforce                                     |
| 4. Quality of local universities                        | 9. Agriculture   |
| 5. Tax base/economics                                   | 10. Materials  |



**Figure 11: Commercial Reasons Located in Tennessee**

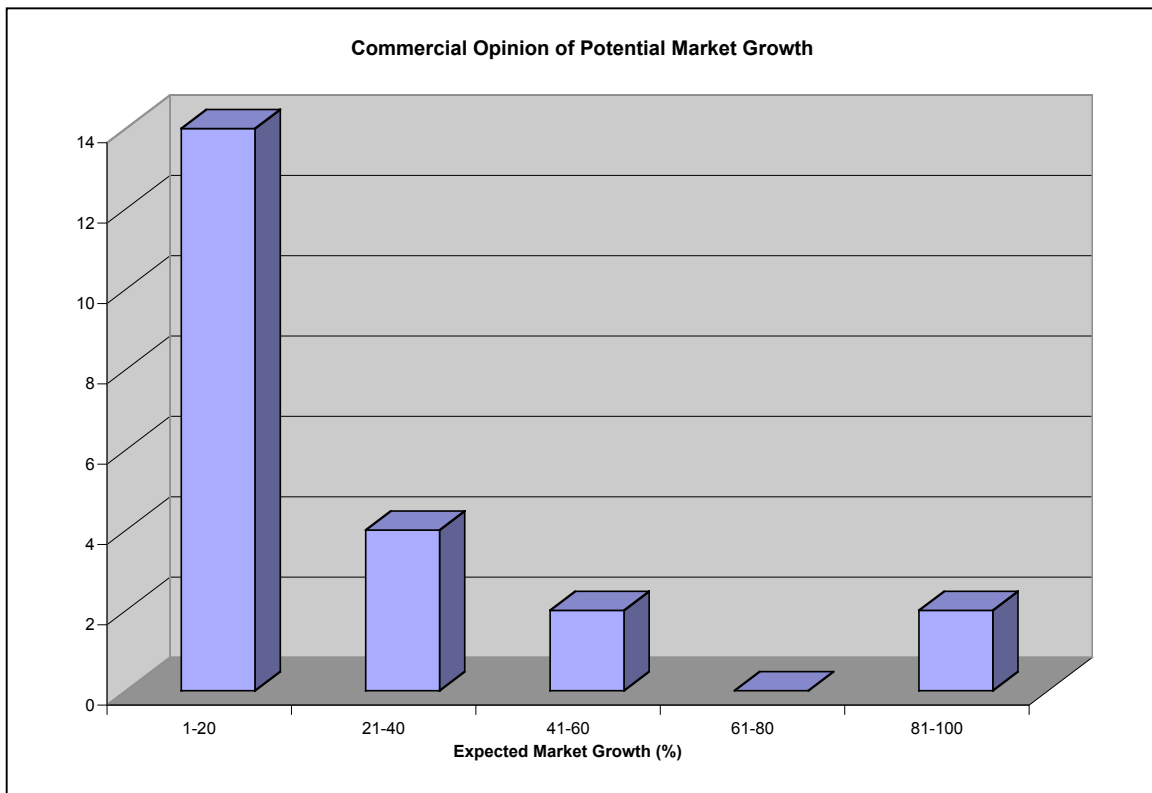
With 44 companies providing information, a total of 50 citations were made. The most frequently cited reason for locating in Tennessee was Community-related issues with 17

citations. By combining the related reasons of spin-off and tech transfer, 14 citations were made. The pre-existing biotech base had eight citations; the pre-existing biotech base was cited only in the West and Middle Tennessee regions.

This data suggests that Community-related issues, such as quality of life, may currently be one of the biggest draws to biotechnology-related businesses in Tennessee. It would also indicate that Tennessee has some existing technology transfer programs and a biotechnology base that is already being utilized.

### **Market Growth**

Commercial respondents were asked to describe their perspective on growth for the market for their product or service by providing a yes/no answer and an option to describe the expected growth. 49 commercial respondents provided expected market growth for their product or service. 22 respondents gave a numeric description of the likely expected percentage of growth in their business. In each of these cases, if a single figure was given, it was accepted as is and if a range was given, the midpoint of the range was used to represent the response.



**Figure 12: Commercial Opinion of Potential Market Growth**

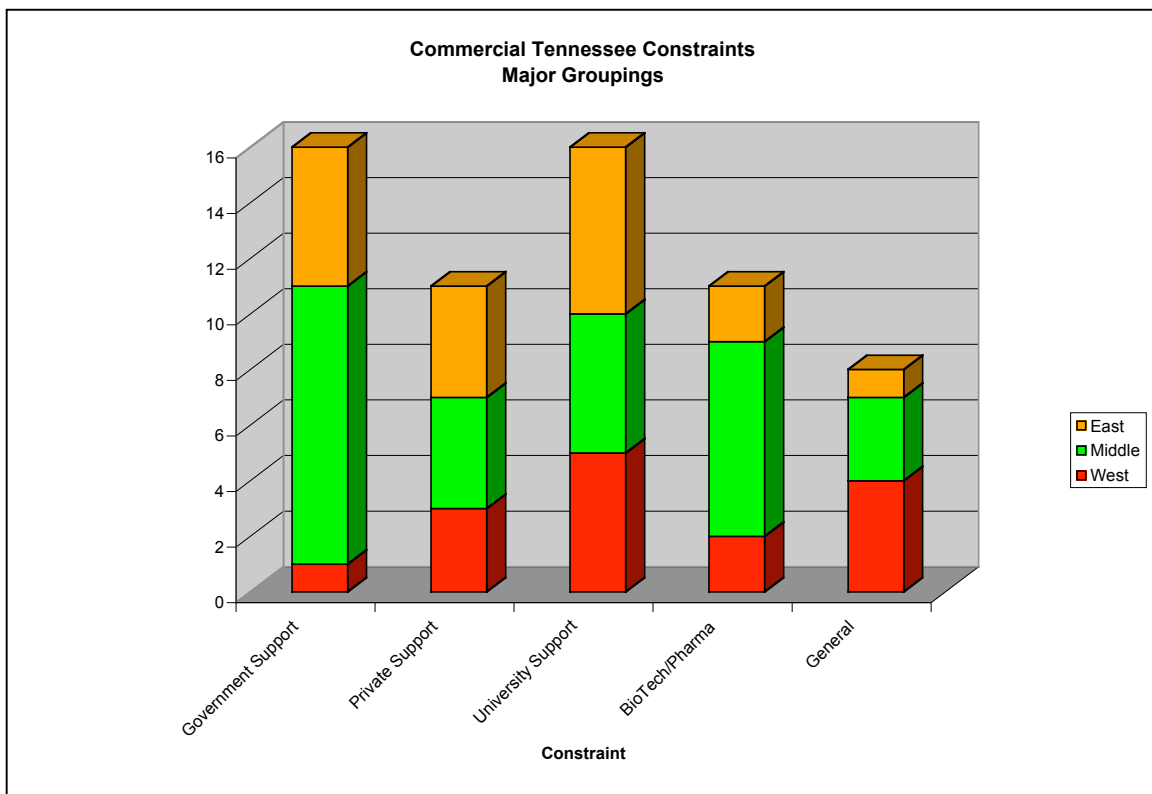
Based on the input provided, the average expected growth rate was approximately 26%. But, as can be seen in the associated chart, the variation in estimates was very high, with a standard deviation of approximately 28%. Two responses indicated 100% growth expected because their businesses were just starting. By calculating excluding these two values (they are approximately 2.7 standard deviations from the mean), the revised average growth estimate is approximately

19% with a standard deviation of 14%. As can be seen from the associated chart, 14 of the original 22 respondents (approximately 63%) expected between 1% and 20% growth in their businesses.

### **Tennessee Constraints**

Commercial respondents were asked what weaknesses exist in Tennessee that constrain their company's growth. 39 responses were provided as free-form text, and five major and 14 sub categories were established to reflect the responses. The five major categories, which primarily on focus areas of support and other larger issue areas, are:

1. Government Support (GS)
2. Private Support (PS)
3. University Support (US)
4. Biotech/Pharma Related (BP)
5. General (GN).



**Figure 13: Commercial Tennessee Constraints (Major Groupings)**

Each company's response could have resulted in multiple categories being cited. A total of 62 citations were recorded. The two major categories with the most citations were University Support and Government Support with 16 citations.

The University Support category included such items as quality of the labor force, quality of the schools, and issues involving transfer of intellectual property. These citations were relatively evenly spread between the three regions of West, Middle, and East Tennessee. Note that any issue cited as a constraint by a respondent might fit into multiple major or sub categories. For

example, universities as well as the public and the private sectors can share responsibility for the quality of the labor force in Tennessee. Many factors affect this issue, and many venues can take action to improve it. For any constraint cited, however, only one major and one sub category were chosen to prevent double counting. The category chosen was that which seemed to be the best fit.

The Government Support category included such items as focus on other programs, licensure requirements for laboratory technicians, lack of small business support, policy issues, and funding availability. The Middle Tennessee region offered a relatively high proportion of Government Support problems with 10 citations. The Private Support category had 11 citations that primarily reflected constraints involving availability of private sector funds and understanding of the biotechnology industry by private-sector funding sources. The Biotech/Pharma category, with 11 citations, included issues involving the lack of a sufficiently large biotech base that could be used to capitalize on synergies, the lack of necessary facilities, and the lack of the ability to run clinical trials. The final major category, General, had 8 citations and included references to lack of a strong biotechnology image by the state and out-of-state competition.

In responding to this question, companies strongly cited each of the three major categories Government, Private, and University Support. This indicates that there is no single area that the respondents believe needs to step up to improve the situation surrounding biotechnology in the state of Tennessee, and that improvement strategies may need to be broadly based.

The 14 subcategories established for a more detailed understanding of the constraints, with an indication the major categories that they relate to, are:

- |                        |  |                                   |
|------------------------|--|-----------------------------------|
| 1. GS – Focus          | 6. PS – Funding                        | 11. BP – Facilities               |
| 2. GS – Licensure      | 7. US – Intellectual Property Transfer | 12. BP – Clinical Trials          |
| 3. GS – Small Business | 8. US – Labor                          | 13. GN – State Image              |
| 4. GS – Policy         | 9. US – Schools                        | 14. GN – Out-of-State Competition |
| 5. GS – Funding        | 10. BP – Synergy                       |                                   |

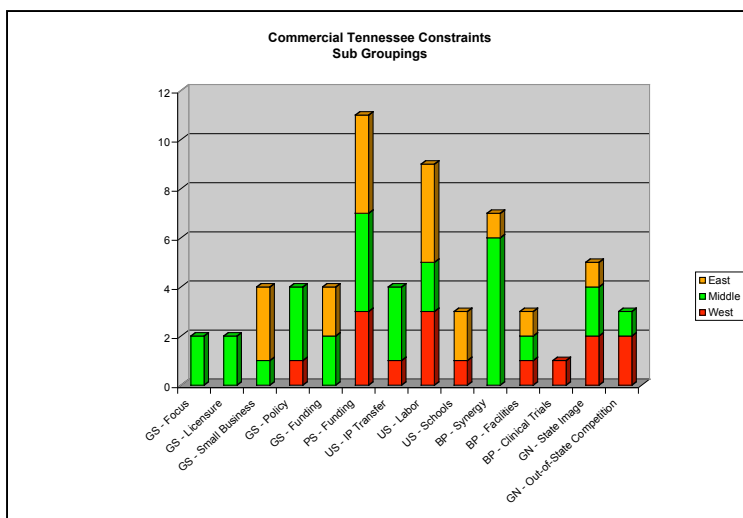


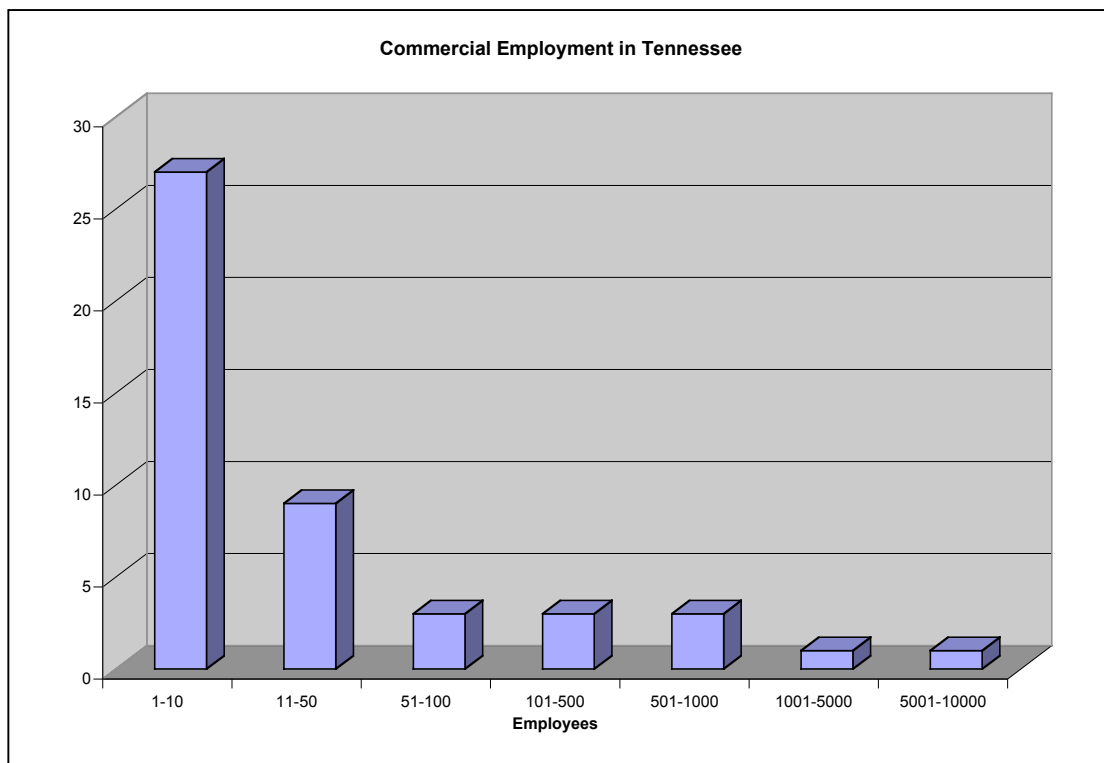
Figure 14: Commercial Tennessee Constraints (Sub Groupings)

The greatest number of citations by subcategory is for PS – Funding, which was cited 11 times and refers to both the availability of funds and the lack of understanding of the biotechnology industry by funding managers. The quality of the labor force in Tennessee was cited nine times. The East Tennessee region cited this problem relatively more often than the Middle Tennessee region. Of the individual subcategories, BP – Synergy ranked third with seven citations; this subcategory refers to the inability to take advantage of natural synergies that occur whenever a sufficiently large biotechnology base is present. Companies in the Middle Tennessee region made six of the seven citations. GN – State Image was fourth.

Combining the GS – Funding and PS – Funding subcategories produces 15 citations that center around funding issues, nearly 40% of the 39 companies responding.

**Commercial Employment in Tennessee**

Commercial respondents were asked to indicate the size of employment of their company in Tennessee. This free-form data was taken as one general indicator of the size/range of sizes of biotechnology and related firms. It is likely that some respondents were precise, while others approximated. The generality of the approximation also likely increased with the size of the employment. All numeric responses were treated as precise enough for the purposes of this Survey, as general indications of size sufficed. Of the 46 companies providing estimates, 27 were very small firms or startups with less than 10 employees. Nine were sized between 11 and 50 employees. The remaining 10 were larger companies with one quoting approximately 8,000 employees. It should not be assumed, however, that all employees indicated were involved in biotechnology or related work.



**Figure 15: Number of Employees - Commercial Employment in Tennessee**

## Key Results from Data Analysis – Academic/Institutional

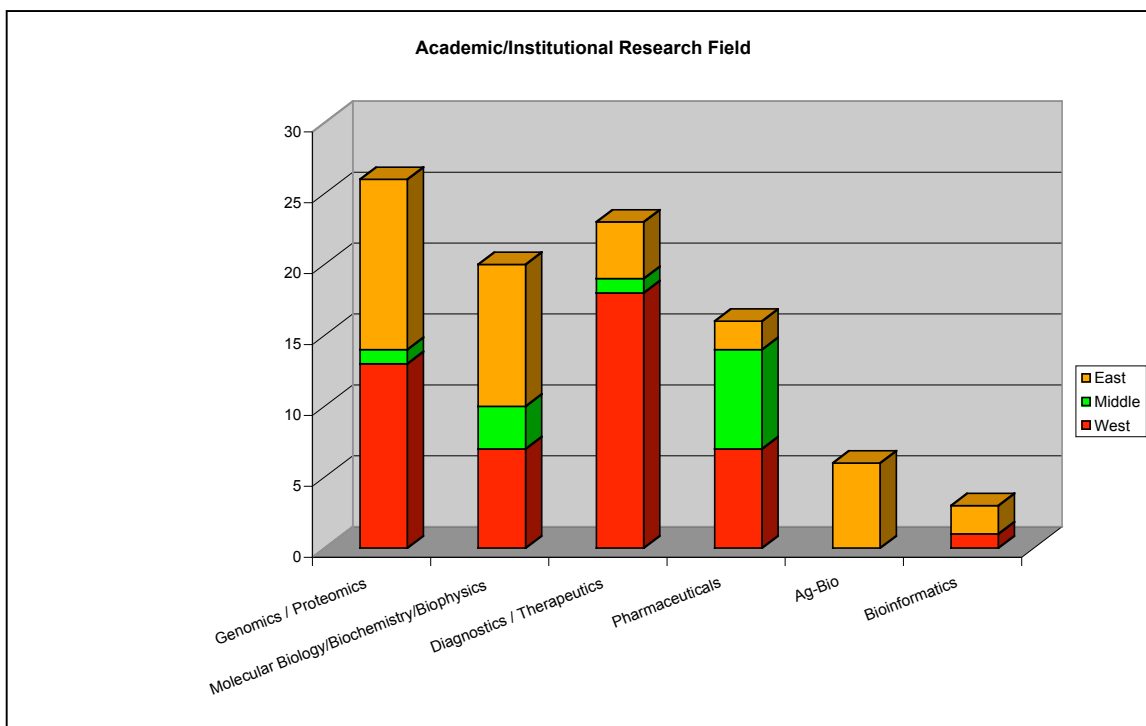
Analysis of Survey data resulted in some interesting or “key” results for the Academic/Institutional sector. Results in several areas appear to have a strong impact on work going forward to build a stronger biotechnology base in Tennessee—these areas are presented in the following sections:

- Academic/Institutional Research Field
- Collaboration
- Academic/Institutional Funding
- Academic/Institutional Commercialization Potential This is never elaborated upon in this section. Either draft a section or remove this reference.

### Academic/Institutional Research Field

Academic/Institutional researchers were asked to select from a list to indicate the field in which they work and were also asked to describe their research using free-form text. The following list reflects the categorization of the 94 respondents:

- Genomics/Proteomics
- Diagnostics/Therapeutics
- Molecular Biology/Biochemistry/Biophysics
- Pharmaceuticals
- Ag-Bio
- Bioinformatics
- Clinical



**Figure 16: Area of Academic/Institutional Research**

Genomics/Proteomics was the largest single category with 26 respondents. Diagnostics/Therapeutics had 22 respondents, Molecular Biology/Biochemistry/Biophysics had 20

respondents, and Pharmaceuticals had 16. These four categories represented approximately 90% of the respondents. While the Middle Tennessee region supplied only 12 of these 94 respondents, approximately 60% of them were in the Pharmaceuticals field. Slightly fewer than 50% of the respondents were from the West Tennessee region, yet they comprised a little over 75% of the Diagnostics/Therapeutics category. While fewer than 40% of the respondents were from the East Tennessee region, 50% of the Molecular Biology/Biochemistry/Biophysics respondents were from that region.

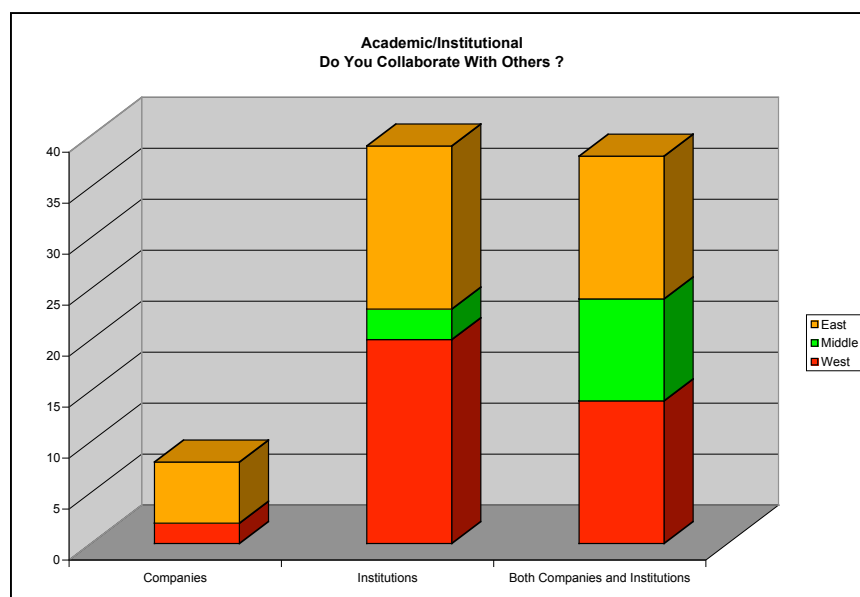
This data would suggest that, if the respondents in each area were considered to be characteristic of that region, the East Tennessee region would be relatively equally invested in the Genomics/Proteomics and Molecular Biology/Biochemistry/Biophysics categories, comprising approximately 60% of this region’s work. Ag-Bio research supplies over 15% of the East Tennessee region’s work. For the West Tennessee region, Diagnostics/Therapeutics represents slightly less than 40% of their work with Genomics/Proteomics providing slightly less than 30%. Together, they comprise slightly more than 65%. Molecular Biology/Biochemistry/Biophysics and Pharmaceuticals together comprise most of the remaining work in the West Tennessee region. The Middle Tennessee region is strongest in Pharmaceuticals.

**Collaboration**

Academic/Institutional respondents were asked to indicate whether they collaborated with other organizations. If so, they were asked to select from the following list to generally indicate the type of organizations with which they collaborated:

- Companies only
- Institutions only
- Both Companies and Institutions.

**Figure 17: Academic/Institutional Collaboration**

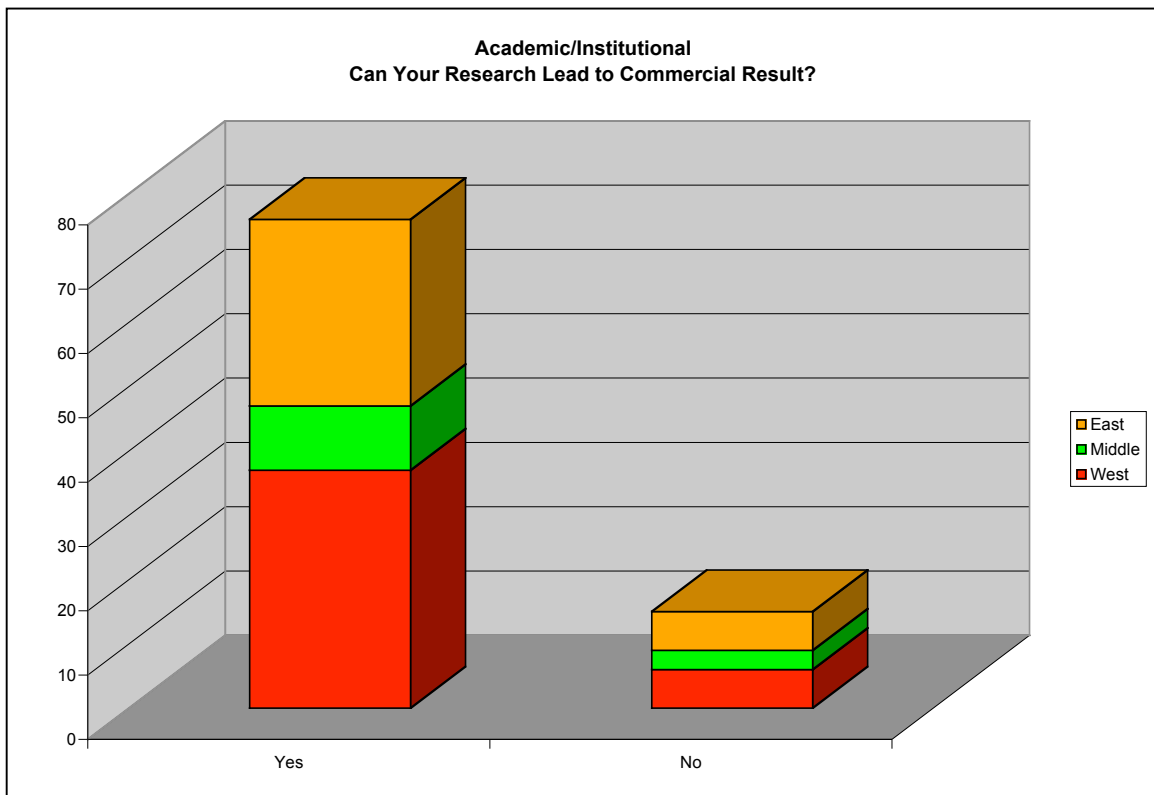


85 respondents indicated they collaborated with other organizations, while 13 indicated they did not. Of the 85, eight claimed collaboration with Companies only while 39 claimed only collaboration with other Institutions. 38 indicated collaboration with both other Companies and

other Institutions. One of the criteria for the success of technology transfer and the building of a biotechnology research base, which can be drawn on to build larger commercial biotechnology, begins with collaboration. 85 of 100 respondents referenced some degree of collaboration indicating that this particular basis for success is in place in Tennessee.

**Commercialization Potential**

The Academic/Institutional respondents were asked if they believed the research in which they were currently engaged had potential for commercialization. Of the 91 respondents to this question, nearly 85% indicated that they believed there was a possibility for commercialization of their current line of research. If this reflects the opinion of all researchers in biotech and related fields in Tennessee, then it is an indicator of a clear potential in Tennessee for the necessary seeds to growth biotech companies.



**Figure 18: Research Leads to Commercial Result (Y/N) (Academic/Institutional)**

### Academic/Institutional Funding

A special survey of the four largest research institutions, The University of Tennessee, Vanderbilt University, Oak Ridge National Laboratory and St. Jude Children's Hospital was conducted to get a solid look at the funding for biotech research at these institutions. The encouraging result was that more than \$580 million of biotech and biotech-related research was funded last year at these four institutions. West Tennessee showed the highest biotech and biotech-related research with about \$270M. Middle Tennessee totals about \$240M. East Tennessee only does about \$75M. The more basic research areas of Molecular Biology/Biochemistry/Biophysics are the highest aggregate research field at about \$160M.

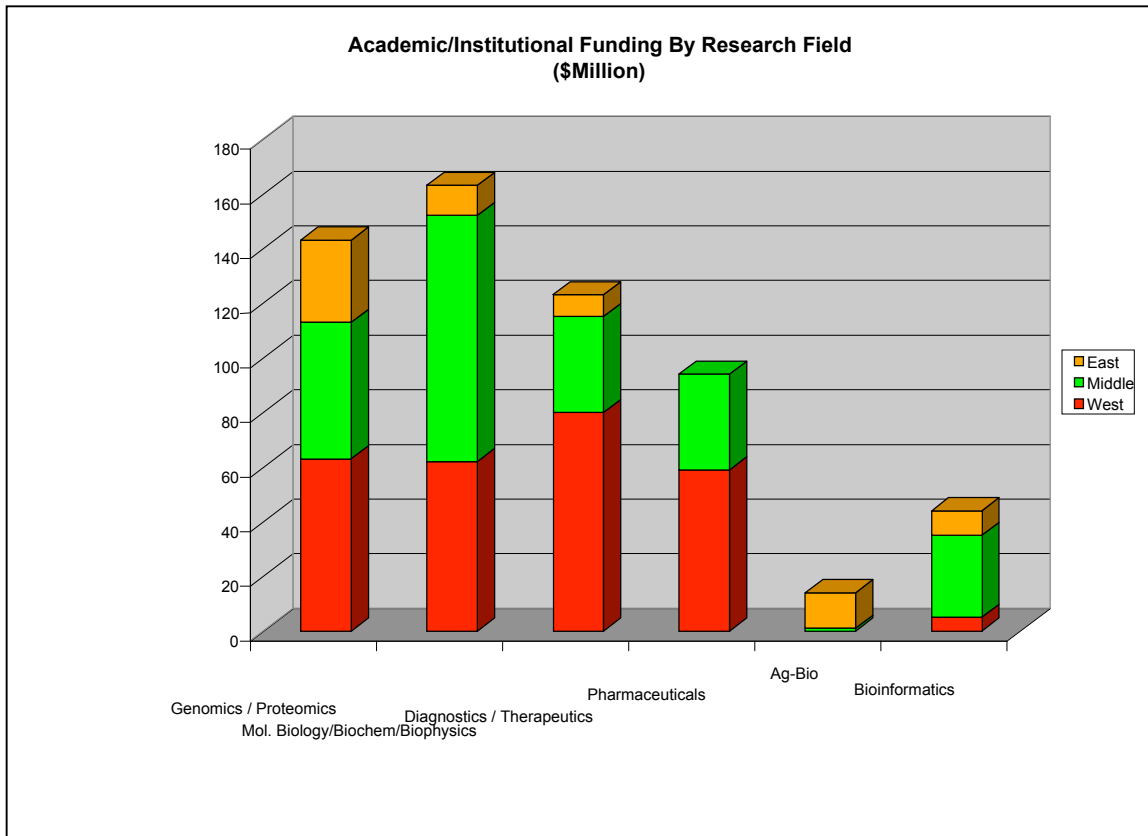


Figure 19: Academic/Institutional Funding by Research Field

## **Key Results from Data Analysis – Combined**

As part of the web Survey, a particular rating was requested of all respondents, whether commercial or institutional. While there are independent commercial and institutional results available, the combined results are presented here for clarity.

### ***Importance/Availability Rating Analysis***

As part of the web Survey, all respondents were asked to rate, on a scale of 1 to 5 (where 5 is the greatest) first the importance to business and then the availability in Tennessee of the following six factors:

1. Access to strong academic institutions conducting basic research in biosciences
2. Access to early-stage capital
3. Successful transfer of government-funded research
4. Specialized facilities including wet laboratory space and specialized equipment
5. Highly skilled workforce
6. Stable and supportive public policy structure

The ratings of these factors were averaged for commercial respondents, academic/institutional respondents, and all respondents. Within each of these three categories, three characterizations for the ratings were produced:

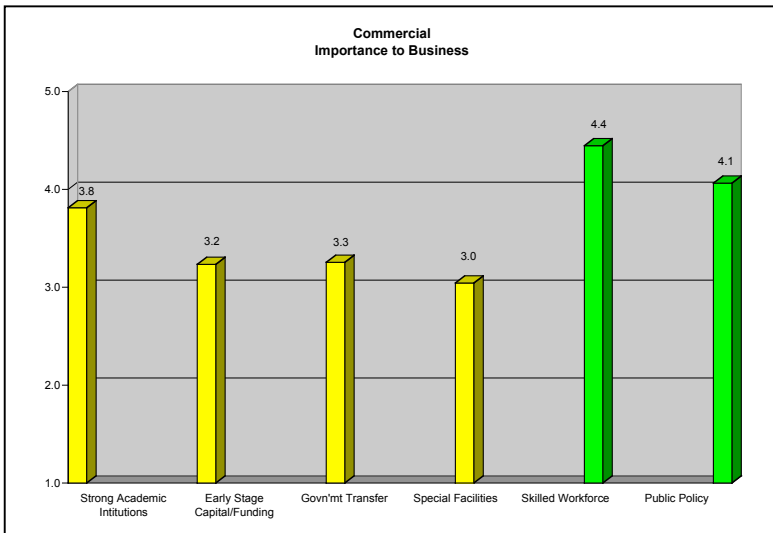
1. comparative importance of the factors to business
2. comparative availability of the factors in Tennessee
3. difference (gap) between importance and availability.

The importance and availability of a factor are not precisely additive characterizations. They were rated on the same scale, and as a means of comparison, the difference between how a factor was rated in importance and how that factor was rated in availability were examined. Therefore, the gap between the two, for each of the categories above, was formed by simple subtraction.

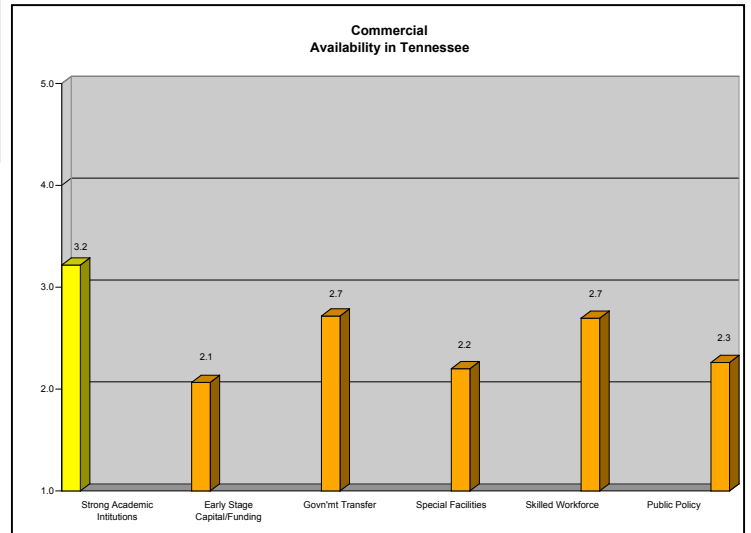
### **Commercial Sector**

For the commercial sector, all factors were rated 3.0 or above in importance. Two factors, a highly skilled workforce and stable and supportive public policy structure, were rated 4.0 or above indicating that the commercial respondents considered these factors of especially high importance to their businesses. Access to strong academic institutions was rated third. The availability of strong academic institutions was rated above a 3.0 and all other factors were rated between 2.0 and 3.0, indicating that the commercial respondents did not consider that any of these factors was very strongly available in Tennessee.

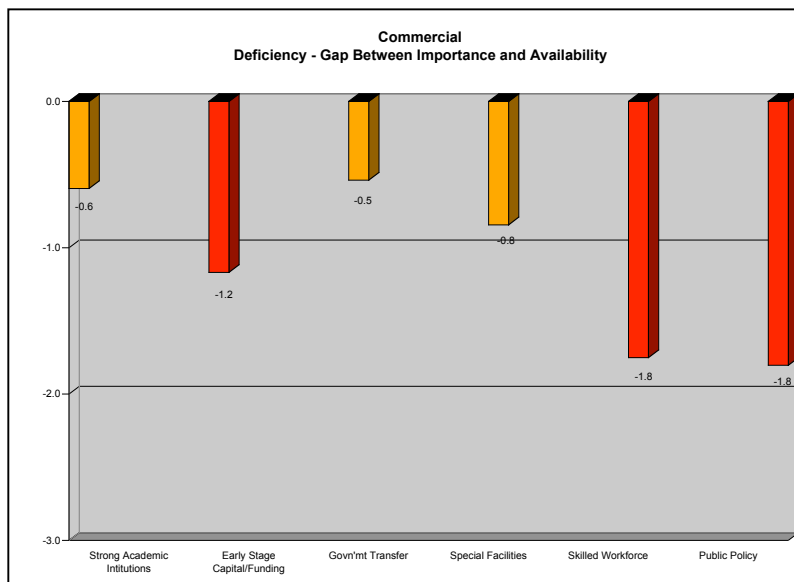
One measure of comparison between the importance and availability of a factor can be formed by subtraction, as has been discussed above. This comparison showed all factors to have been rated stronger in importance than in availability by the aggregate of commercial respondents. Three factors (the availability of early stage capital, a highly skilled workforce, and stable and supportive public policy) show a gap of 1.0 or greater, with highly skilled workforce and stable and supportive public policy showing a gap of 1.8 each. These would indicate that the commercial respondents considered the difference between the importance and availability of these three factors to be greater than the corresponding differences of the other three.



**Figure 20: Commercial Importance**



**Figure 21: Commercial Availability in Tennessee**

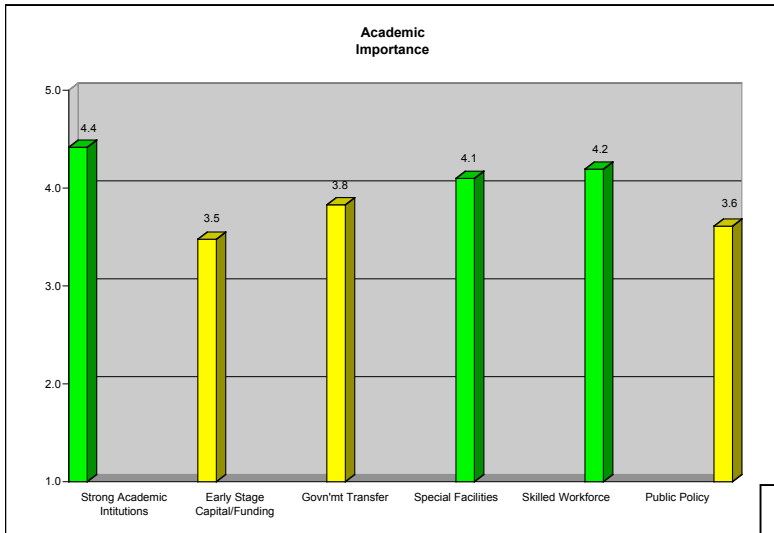


**Figure 22: Gap Between Importance and Availability (Commercial Deficiency)**

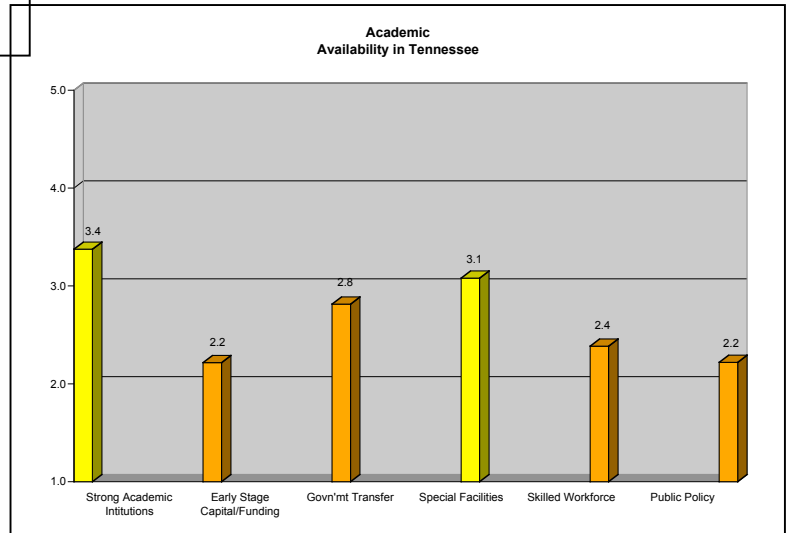
### **Academic/Institutional Sector**

For the academic/institutional sector, all factors were rated higher than 3.0 in importance. Three factors (access to strong academic institutions, a highly skilled workforce, and special facilities) were rated 4.0 or above indicating that the academic/institutional respondents considered these factors of especially high importance to their work. Two factors, the availability of strong academic institutions and special facilities, were rated above a 3.0 and all other factors were rated between 2.0 and 3.0. This would indicate that the academic/institutional respondents did not consider any of these factors to be very strongly available in Tennessee.

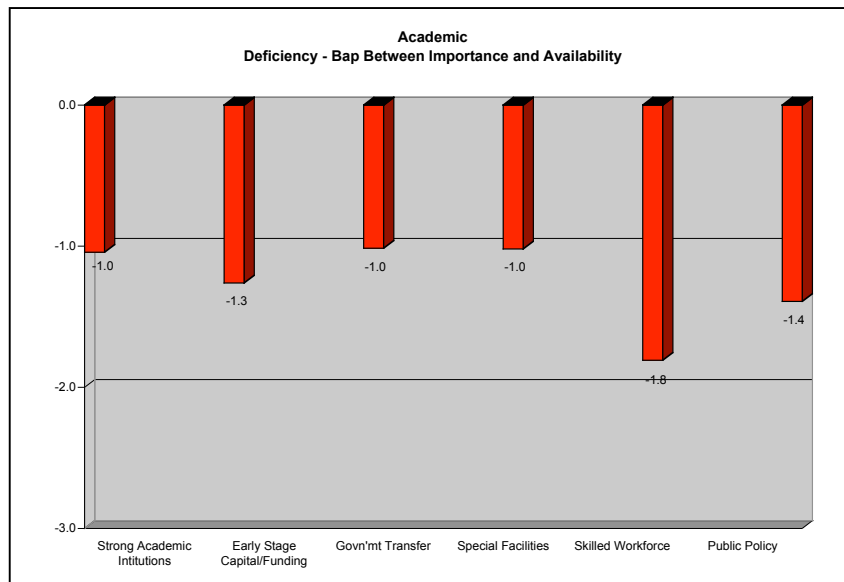
The comparison between importance and availability again showed all factors to have been rated stronger in importance than in availability by the aggregate of academic/institutional respondents. All factors show a gap of 1.0 or greater (with a highly skilled workforce showing a gap of 1.8), indicating that the academic/institutional respondents considered the difference between the importance and availability of all of these factors to perhaps be significant.



**Figure 23: Academic Importance**



**Figure 24: Academic Availability in Tennessee**

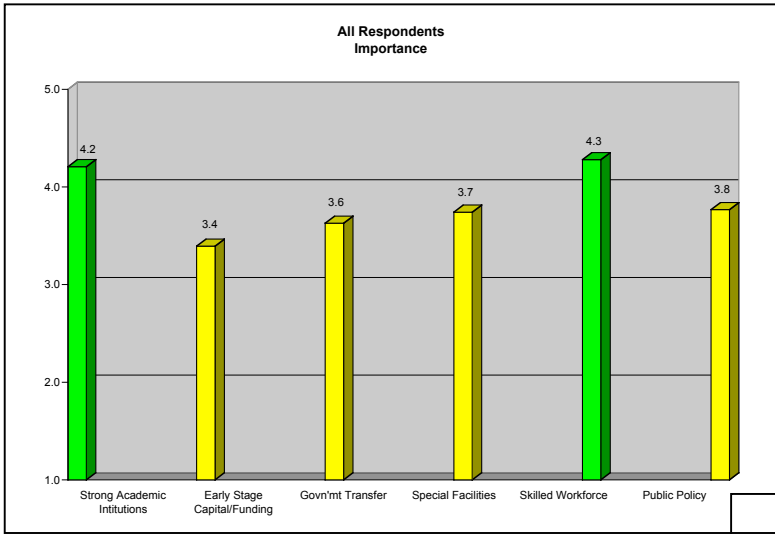


**Figure 25: Gap Between Importance and Availability (Academic Deficiency)**

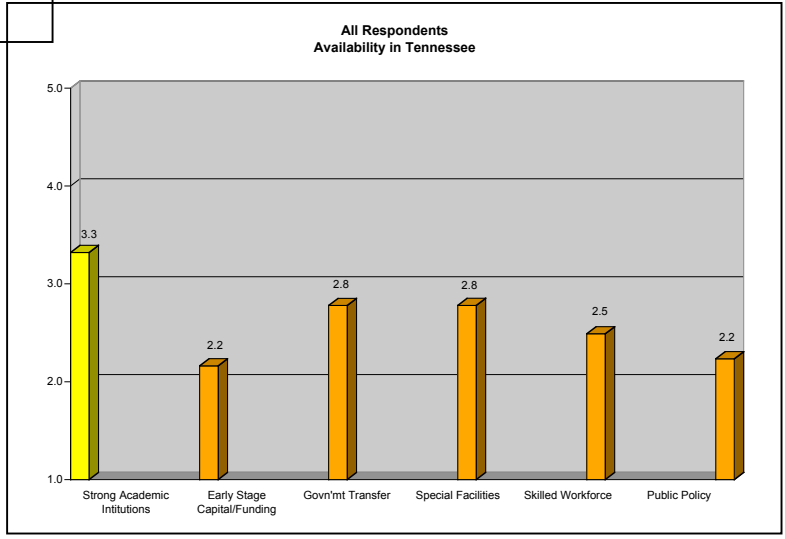
### **All Respondents**

When aggregating all respondents, two factors (a highly skilled workforce and strong academic institutions) were rated 4.0 or above indicating that overall the respondents considered these factors of the highest importance to biotechnology in Tennessee. The availability of strong academic institutions was rated above a 3.0, however, all other factors were rated between 2.0 and 3.0, indicating that overall the respondents did not consider any of these factors to be strongly available in Tennessee.

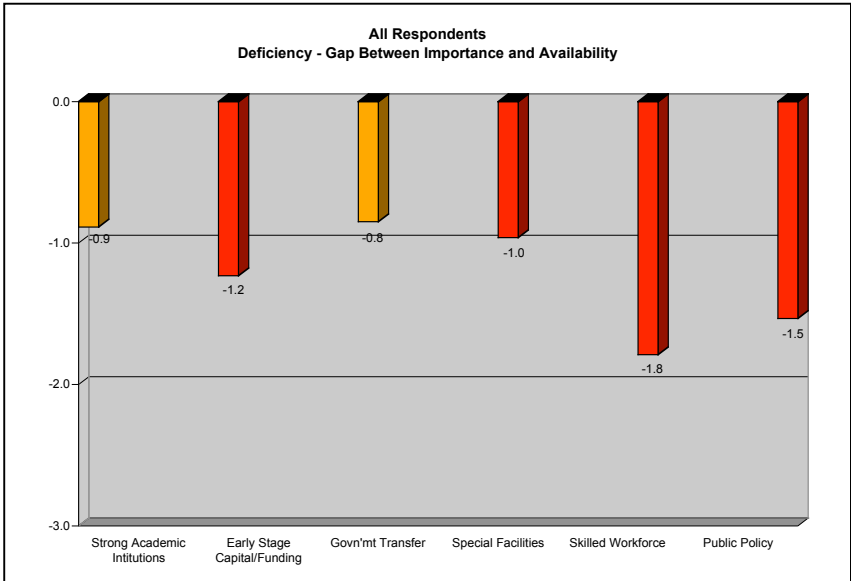
For the comparison between importance and availability, four factors (availability of early-stage capital or funding, special facilities, a highly skilled workforce, and stable and supportive public policy) show a gap of 1.0 or greater with highly skilled workforce and stable and supportive public policy showing a gap of 1.8 and 1.5 respectively. This would indicate that overall the respondents considered the difference between the importance and availability of these factors to be greater than the corresponding differences between the others. There were approximately twice as many academic/institutional respondents than commercial respondents in the aggregate.



**Figure 26: Areas of Importance (All Respondents)**



**Figure 27: Availability in Tennessee (All Respondents)**



**Figure 28: Gap Between Importance and Availability (All Respondents)**

### ***Importance/Availability Conclusions***

An overall look at these results indicate that, for the Survey respondents, the greatest difference between importance to the success of biotechnology businesses in the state of Tennessee and the current availability in Tennessee of the factors considered would be a highly skilled workforce. A stable and supportive public policy rates the second greatest difference between importance and availability and access to early-stage capital/funding is third. It could be conjectured that the respondents consider a highly skilled workforce to be the greatest stumbling block to biotechnology investment in Tennessee.

## Appendix B: Commercial Respondents

Company	Web Site	TN Region	Office Location	Location of Headquarters	Business Focus	Product or Service
Accredo Health, Inc.	<a href="http://www.accredohealth.net/nova">www.accredohealth.net/nova</a>	West	Memphis	Memphis, TN	Pharmaceutics	Leading provider of contract pharmacy services to the biopharmaceutical industry.
Aegis Sciences Corporation		Middle	Nashville	Nashville, TN	Diagnostics / Therapeutics	Forensic analysis for sport, workplace, schools, medical examiner
AngioPath, Inc.	<a href="http://www.AngioPath.com">www.AngioPath.com</a>	Middle	Franklin	Franklin, TN	Diagnostics / Therapeutics	API is an early stage biopharmaceutical company with plans to develop cancer vaccines as well as drugs and diagnostics based on proprietary technologies developed at Vanderbilt.
ApoCom Genomics	<a href="http://www.apocom.com">www.apocom.com</a>	East	Knoxville	Knoxville, TN	Bioinformatics	Bioinformatics software, data base mining and management
Atom Sciences, Inc	<a href="http://www.atom-sci.com">http://www.atom-sci.com</a>	East	Oak Ridge	Oak Ridge, TN	Diagnostics / Therapeutics	DNA array for bacteria and other pathogens.
Bioinventions LLC		East	Johnson City	Johnson City, TN	Pharmaceutics	For the most part, Bioinventions LLC will focus on the development of biomedical intellectual property from discovery to Phase I studies. Under special circumstances a Phase II study could be considered.
BioMimetic Pharmaceuticals, Inc.	<a href="http://www.biomimetics.com">www.biomimetics.com</a>	Middle	Franklin	Franklin, TN	Diagnostics / Therapeutics	Developing tissue engineering therapeutics for orthopedic, periodontal, dental and craniofacial fields. Also developing diagnostic for periodontal applications.
BioVentures, Inc.	<a href="http://www.bioventures.com">www.bioventures.com</a>	Middle	Murfreesboro	Murfreesboro, TN	Genomics / Protoemics	Products for Molecular Biology and Genetic Research
Celeris Corporation	<a href="http://www.celeriscorp.com">www.celeriscorp.com</a>	Middle	Nashville	Nashville, TN	Clinical	Company provides clinical research services to pharmaceutical, biotech and device manufacturers.

Company	Web Site	TN Region	Office Location	Location of Headquarters	Business Focus	Product or Service
Cell Genesys, Inc.	www.cellgenesys.com	West	Memphis	Foster City, CA	Diagnostics / Therapeutics	Cell Genesys is focused on the development and commercialization of innovative therapeutic products for cancer based on gene therapy technologies. The company is pursuing three cancer product platforms;GVAX® cancer vaccines, oncolytic virus therapies and in vivo cancer gene therapies. Clinical trials of GVAX® vaccines are under way in prostate cancer, lung cancer, pancreatic cancer, leukemia and myeloma. Clinical trials of oncolytic virus therapies include CG7060 and CG7870 in prostate cancer. Preclinical stage programs include oncolytic virus therapies and gene therapies for multiple types of cancer. Cell Genesys' majority-owned subsidiary, Ceregene, Inc., is focused on gene therapies for neurologic disorders.
Concepto Diagnostics Corp	www.conceptodiagnos-tics.com	East	Knoxville	Knoxville, TN	Ag-Bio	Diagnostic Lateral Flow Tests to identify the open" cow or horse. This is a big dollar savings to the dairyman
Consilience Group, LLC	www.consiliencegroup.com	West	Memphis	Memphis, TN	Business Consulting	Market Viability Analysis, Start Up Business Planning, Marketing strategies, Other Strategic Consulting
Cumberland Emerging Technologies Inc	www.cet-fund.com	Middle	Nashville	Nashville, TN	Business Consulting	To bring biomedical technologies and products to the marketplace from research carried out at Vanderbilt and other regional laboratories and universities
Cumberland Pharmaceuticals Inc	www.cumberlandpharma.com	Middle	Nashville	Nashville, TN	Pharmaceutics	Pharmaceutical products - an emerging pharmaceutical company. Its mission is to acquire rights to branded, prescription products and grow them through marketing to targeted physician segments.
Eastman Chemical Company	www.eastman.com	East	Kingsport	Kingsport, TN	Supplier	Eastman manufactures chemicals and plastics from a variety of raw materials, including oil, natural gas, coal, and biomass
eSpin	www.nanospin.com	East	Chattanooga	Chattanooga, TN	Supplier	Nanofibers

Company	Web Site	TN Region	Office Location	Location of Headquarters	Business Focus	Product or Service
Genetics Associates, Inc.	www.geneticsassociates.com	Middle	Nashville	Nashville, TN	Diagnostics / Therapeutics	Cytogenetic (chromosome)diagnostic studies-medical laboratory
Greystone Medical		West	Memphis	Memphis, TN	Pharmaceutics	Wound care drug
H3GM	www.h3gm.com	Middle	Nashville	Nashville, TN	Business Consulting	Legal services
ICON Clinical Research	www.iconus.com	Middle	Brentwood	Dublin, Ireland	Clinical	Development services to the Pharmaceutical, Biotech and Medical Device Industry
IdentiChem		East	Knoxville	Knoxville, TN	Diagnostics / Therapeutics	Current focus is on Neurotech and the application of nonlinear dynamics to epileptic seizure analysis.
ImTek, Inc.	www.imtekinc.com	East	Knoxville	Knoxville, TN	Supplier	Diagnostic imaging hardware and software for laboratory animal research.
King Pharmaceuticals, Inc.	www.kingpharm.com	East	Bristol	Bristol, TN	Pharmaceutics	Pharmaceutical Products (solid oral, liquid, ointment, cream, sterile injectable)
Kraft Search Associates	www.kraftsearch.com	Middle	Nashville	Nashville, TN	Business Consulting	We recruit middle management & senior management primarily within the finance & business development competencies.
Lifeblood	www.lifeblood.org	West	Memphis	Memphis, TN	Supplier	Human-derived biological materials, primarily those procured/produced from whole blood. additionally we are interested in creating cGMP compliant contract manufacturing space to produce human derived biopharmaceuticals and providing these services to patients on a regional and national basis.
Methodist Healthcare - Germantown Hospital		West	Germantown	Memphis, TN	Diagnostics / Therapeutics	Hospital inpatient and outpatient services

Company	Web Site	TN Region	Office Location	Location of Headquarters	Business Focus	Product or Service
Microarrays, Inc	www.microarrays.com	Middle	Nashville	Nashville, TN	Genomics / Protoemics	Microarrays, Inc. offers custom microarray manufacturing services to both academic and industrial clients.
Molecular Design International, Inc.	www.moleculardesign.com	West	Memphis	Memphis, TN	Pharmaceutics	We discover drugs and out license at the IND level of development.
Nashville Health Care Council	http://healthcarecouncil.com	Middle	Nashville	Nashville, TN	Business Consulting	An association of health care industry leaders working together to further establish Nashville's position as the nation's health care industry capital.
Onyx Medical Corp		West	Memphis	Memphis, TN	Medical Devices	Orthopedic implant -Onyx is a contract manufacturer of implants
PerkinElmer Life Sciences	www.perkinelmer.com	Middle	Nashville	Boston, MA	Supplier	Complete Instrument Product Lines and Consumables for Genomics, Proteomics, and High Throughput Screening
PETNET Pharmaceuticals		East	Knoxville	Knoxville, TN	Diagnostics / Therapeutics	Positron Emission Tomography (PET) Radiopharmaceuticals
PPS, Inc. DBA Comprehensive Pharmacy Services		West	Memphis	Memphis, TN	Pharmaceutics	Provide pharmacy management support to hospitals, clinical, regulatory, operational, managerial, therapeutic, and financial support. We also manage clinical trials in multiple states.
Praxis Communications, Inc.	www.gopraxis.com	Middle	Brentwood	Brentwood, TN	Business Consulting	Marketing communications company specializing in the recruitment of patients for clinical trials on behalf of pharmaceutical & biotech companies
Premier Micronutrient Corp.	premiermicronutrients.com	Middle	Nashville	Nashville, TN	Diagnostics / Therapeutics	Disease management company combining patented micronutrient formulations with disease specific clinical protocols for prevention and adjunctive treatment of medical conditions.
Protherics Inc.	www.protherics.com	Middle	Brentwood	London	Diagnostics / Therapeutics	Therapeutic Antibodies and Polypeptide Vaccines

Company	Web Site	TN Region	Office Location	Location of Headquarters	Business Focus	Product or Service
Qgenics Biosciences, Inc.	www.qgenics.com	East	Knoxville	Knoxville, TN	Genomics / Protoemics	QGENICS is currently developing an integrated protein microchip for use in high-resolution protein analysis.
Raymond James & Associates	www.rjcapitalmarkets.com	Middle	Nashville	St. Petersburg, FL	Business Consulting	Investment banking services
SAIC	www.saic.com	East	Oak Ridge	San Diego, CA	Business Consulting	Information Systems
Smith and Nephew	www.smith-nephew.com	West	Memphis	London	Medical Devices	Orthopaedic Implants
Stoneville Pedigreed Seed Company	www.stoneville.com	West	Memphis	Memphis, TN	Ag-Bio	Cotton planting seeds with value-added traits from biotechnology
Tennessee Commerce Bank	www.tncommercebank.com	Middle	Franklin	Franklin, TN	Business Consulting	Cash management, lines of credit, checking and savings instruments. Focus on professionals, small and mid-sized businesses.
The CFP Group	www.cfp-group.com	Middle	Nashville	Nashville, TN	Business Consulting	We provide a variety of services including: capital expenditure budgeting; zoning / permitting; licensure research; conceptual design; design development and equipment planning; construction documents; construction administration; Construction program management; operational planning; needs analysis; process planning; real estate and physical plant assessments; facility programming; development support for life sciences, research, and laboratory industries.
Theragenics Corporation	www.theragenics.com	East	Oak Ridge	Georgia	Medical Devices	Radioactive seed implants used primarily in treatment of early stage prostate cancer
Titan	www.titan.com	Middle	Nashville	San Diego, CA	Supplier	Titan is a total solutions provider of automation and informatics equipment to laboratories throughout the world. Titan provides both products and custom services to the biotech marketplace.

Company	Web Site	TN Region	Office Location	Location of Headquarters	Business Focus	Product or Service
Transnetyx, Inc.	www.transnetyx.com	West	Cordova	Cordova, TN	Supplier	Transnetyx had developed an automated, high-throughput genetic testing service for transgenic, knock-out, and knock-in mice. The service provides customers with results within 24 hours, compared to 4-5 days utilizing current techniques. Transnetyx is targeting academic researchers, commercial mouse providers, and pharmaceutical companies.
TyDye BioInformatics, LLC	www.tydyebio.com	Middle	Franklin	Franklin, TN	Bioinformatics	Bioinformatics Services
VDDI, Pharmaceuticals	www.virtualdrugdevelopment.com	Middle	Brentwood	Brentwood, TN	Pharmaceutics	Development of therapies for cancer, cardiovascular disease, and infectious diseases
Wright Medical Group, Inc.	www.wmt.com	West	Arlington	Arlington, TN	Medical Devices	Orthopaedic devices

## Appendix C: Academic/Institution Responses (by Respondent Grouped by Institution)

Institution	Web Site	Region	Research Field	Research Description
East Tennessee State University	<a href="http://www.etsu.edu">www.etsu.edu</a>	East	Genomics / Proteomics	Study the structure and function of proteinase enzymes found in human mast cells.
East Tennessee State University		East	Ag-Bio	Molecular controls of Insect diapause and mode of action of juvenile hormone
East Tennessee State University		East	Pharmaceuticals	Mechanism of action of new, novel antibiotics
East Tennessee State University	<a href="http://www.etsu.edu">www.etsu.edu</a>	East	Genomics / Proteomics	Characterization of gene network responsible for insect diapause.
East Tennessee State University	<a href="http://www.etsu.edu">www.etsu.edu</a>	East	Genomics / Proteomics	Examining early land plant relationships using comparisons of gene sequences
East Tennessee State University		East	Genomics / Proteomics	Mechanisms of DNA oxidative damage by chemotherapeutic drugs and excess metabolites and the protection of DNA by some common, dietary antioxidants.
East Tennessee State University		East	Molecular Biology / Biochemistry / Biophysics	My laboratory is focused on sexually transmitted diseases of humans. Because sexually transmitted diseases cause enormous morbidity and mortality world wide, these studies have the potential to significantly impact human health. Bacterial/viral co-infection project: Herpes Simplex type 2 (HSV-2) and Chlamydia trachomatis are common causes of sexually transmitted disease, 500,000 new cases of HSV-2 and 4 million new cases of C. trachomatis are reported annually in the US. Epidemiological studies suggest that double infection with HSV-2 and C. trachomatis occurs. We are currently testing the hypothesis that co-infection will alter replication and/or pathogenesis of these agents. Chlamydial persistence project: Chlamydiae have the ability to

Institution	Web Site	Region	Research Field	Research Description
				establish persistent infection of host cells/organisms under specific environmental conditions. One inducer of persistence is penicillin, a beta-lactam antibiotic. Currently, we are evaluating the ability of various second and third generation beta-lactam antibiotics to indu
East Tennessee State University		East	Molecular Biology / Biochemistry / Biophysics	Electrophysiological approach to study the role of membrane ion channels in controlling cell proliferation and tumor cell migration (metastases)
JC/JWC Economic Development Board	<a href="http://www.jcedb.org">www.jcedb.org</a>	East		
Metro Nashville Public Schools		Middle	Molecular Biology / Biochemistry / Biophysics	I have created an innovative, ground-breaking molecular research class-the first in the state. One of my goals is to create similar programs as well as new biotech courses and implement them across the state. These courses would not only serve the education population, but would serve as training facilities for industry as well. Another goal is to create mentoring/research opportunities for faculty and students in the field as well as have students involved in research competitions and publishing their work. Four of my students from my molecular course wrote and received a grant to fund their research and had their papers published in the Tennessee Academy of Science Journal.
Oak Ridge National Laboratory	<a href="http://www.ornl.gov">http://www.ornl.gov</a>	East	Genomics / Proteomics	Diverse research in mouse genomics, computational biology and bioinformatics, development of biosensors and biomaterials, and perform research in bioprocessing
Oak Ridge National Laboratory		East	Bioinformatics	We're developing a charged particle 3-dimensional transport computer code to simulate radiation treatments using discrete ordinates methodology.
Oak Ridge National Laboratory	<a href="http://www.ct.ornl.gov">www.ct.ornl.gov</a>	East	Molecular Biology / Biochemistry / Biophysics	R&D in Bioprocessing, bioconversion, bioremediation - targeted R&D for fuels, chemicals, fossil fuels, environmental, renewables applications using microbiology, molecular biology, enzyme modifications, separations and process integration and modeling.
Oak Ridge National Laboratory		East	Genomics / Proteomics	Identifying point mutations in the mouse genome and using selected mouse models for investigating human disease.

Institution	Web Site	Region	Research Field	Research Description
Oak Ridge National Laboratory	<a href="http://compbio.ornl.gov">http://compbio.ornl.gov</a>	East	Bioinformatics	Bioinformatics tool development biological pathway studies
Oak Ridge National Laboratory		East	Genomics / Proteomics	Microbial genomics, microbial physiology, bioremediation
Oak Ridge National Laboratory	<a href="http://www.ornl.gov">www.ornl.gov</a>	East	Genomics / Proteomics	Interfacing nanoscale devices to the molecular processes of intact whole cells
Oak Ridge National Laboratory		East	Genomics / Proteomics	Using molecular techniques to conduct ecological studies on forest trees and other plants. Using genomics to discover methods to enhance carbon sequestration by trees.
Oak Ridge National Laboratory		East	Diagnostics / Therapeutics	
Oak Ridge National Laboratory		East	Diagnostics / Therapeutics	Fabrication and implementation of nanoscale electrochemical arrays for probing intact cells and tissue.
Oak Ridge National Laboratory		East	Molecular Biology / Biochemistry / Biophysics	Carbon sequestration, microbial mineral formation, doped magnetite and ferrite production, biogeochemistry of methane hydrates, life in extreme environments
Quillen College of Medicine, East Tennessee State University		East	Molecular Biology / Biochemistry / Biophysics	The internal fatty acylation of a benign protein with two fatty acids turns it into a toxic protein, hemolysin. We are studying the biochemistry of the internal fatty acylation of the protein.
Quillen College of Medicine, East Tennessee State University		East	Genomics / Proteomics	Understand the molecular mechanism of nucleotide excision repair (NER) in both E. coli and human systems. As a cellular defense system, DNA repair is an extremely important biological process that maintains the fidelity and integrity of human genetic materials since DNA damage is ultimately responsible for most of human cancers. As one of the DNA repair pathways, nucleotide excision repair removes a large variety of DNA lesions induced by various environmental pollutants, and other genotoxic reagents and

Institution	Web Site	Region	Research Field	Research Description
				carcinogens.
Regional Medical Center at Memphis		West	Diagnostics / Therapeutics	Clinical trials
St. Jude Children's Research Hospital	<a href="http://www.stjude.org">www.stjude.org</a>	West	Bioinformatics	
St. Jude Children's Research Hospital	<a href="http://www.stjude.org">http://www.stjude.org</a>	West	Genomics / Proteomics	Gene expression analysis proteomics/mass spectrometry
St. Jude Children's Research Hospital		West	Diagnostics / Therapeutics	Interspecies transmission of influenza viruses
St. Jude Children's Research Hospital		West	Molecular Biology / Biochemistry / Biophysics	Cell cycle research and cancer
St. Jude Children's Research Hospital	<a href="http://www.stjude.org">www.stjude.org</a>	West	Diagnostics / Therapeutics	Molecular microbiology, molecular epidemiology of bacteria infections, vaccines
St. Jude Children's Research Hospital		West	Diagnostics / Therapeutics	Novel methods of magnetic resonance imaging (MRI) to reveal diffuse disease states not visualized by current MRI
St. Jude Children's Research Hospital	<a href="http://www.stjude.org">http://www.stjude.org</a>	West	Pharmaceuticals	Structural Biology, Drug design
St. Jude Children's Research Hospital	<a href="http://www.stjude.org">www.stjude.org</a>	West	Diagnostics / Therapeutics	Vaccine development

Institution	Web Site	Region	Research Field	Research Description
St. Jude Children's Research Hospital	<a href="http://www.stjude.org">http://www.stjude.org</a>	West	Genomics / Proteomics	We are looking for the genes that confer sensitivity to environmental toxins that lead to the development of Parkinson's disease
St. Jude Children's Research Hospital	<a href="http://www.stjude.org">www.stjude.org</a>	West	Molecular Biology / Biochemistry / Biophysics	Brain Development Oncogenes and Cancer Brain Tumors
St. Jude Children's Research Hospital		West	Diagnostics / Therapeutics	Drug development for therapy and prophylaxis of Pneumocystis carinii pneumonia.
The Center for Environmental Biotechnology	<a href="http://www.ceb.utk.edu">www.ceb.utk.edu</a>	East	Diagnostics / Therapeutics	CEB is involved in the development of bioluminescent bioreporter bacteria and linking them with integrated circuits. This will enable real-time, on-line, remote sensing of various chemical/biological agents. Applications range from environmental monitoring, defense, and medical applications.
Tristar Enterprises, Inc.	<a href="http://www.tristarenterprise.org">www.tristarenterprise.org</a>	West	Diagnostics / Therapeutics	Tristar is a business development company that assists UT Medical Center faculty with entrepreneurial activities. Tristar does not sponsor or conduct research per se. As such, many of the questions below are not entirely pertinent to Tristar. I have tried to answer the ones that apply to our activity.
University of Tennessee	<a href="http://pharmacy.utmem.edu/">http://pharmacy.utmem.edu/</a>	West	Pharmaceuticals	1.) Pharmacokinetic, pharmacodynamic and biopharmaceutical research in drug development and dosage form optimization 2.) Pharmacogenetic and Pharmacogenomics research in inflammatory diseases with focus on pulmonary inflammation
University of Tennessee		West	Genomics / Proteomics	Cell biological studies of the rate limiting step in fat absorption.
University of Tennessee	<a href="http://www.utmem.edu">www.utmem.edu</a>	West	Pharmaceuticals	New drug development, dosage form design and development, clinical trials
University of Tennessee		West	Molecular Biology / Biochemistry / Biophysics	Monocyte function in diabetes mellitus and periodontal disease

Institution	Web Site	Region	Research Field	Research Description
University of Tennessee	<a href="http://www.utmem.edu/pharmacology">www.utmem.edu/pharmacology</a>	West	Pharmaceuticals	Basic research to identify novel mechanisms of antidepressant activity
University of Tennessee		West	Genomics / Proteomics	Protein sorting in erythroid and epithelial cells
University of Tennessee		West	Diagnostics / Therapeutics	NIH and Biotech company sponsored research in pathogenesis of Respiratory Syncytial Virus Infections. Also, broad practical research in viral diagnostics using nucleic acid amplification technologies
University of Tennessee	<a href="http://physio1.utmem.edu">http://physio1.utmem.edu</a>	West	Molecular Biology / Biochemistry / Biophysics	Cardiovascular research. Arterial smooth muscle cell physiology. Ion channels. Calcium signaling. Hypertension.
University of Tennessee	<a href="http://www.utmem.edu/pathology">www.utmem.edu/pathology</a>	West	Genomics / Proteomics	Mechanism of cytokine action
University of Tennessee		West	Molecular Biology / Biochemistry / Biophysics	Signal transduction, apoptosis, hepatocarcinogenesis, breast cancer
University of Tennessee		West	Genomics / Proteomics	Activation of macrophages and neutrophils, and their role in resistance to infection.
University of Tennessee		West	Pharmaceuticals	Drug design and synthesis
University of Tennessee		West	Molecular Biology / Biochemistry / Biophysics	Regulation of gene expression
University of Tennessee		East	Ag-Bio	Plant-microbe interactions/nitrogen fixation/bioremediation

Institution	Web Site	Region	Research Field	Research Description
University of Tennessee		East	Ag-Bio	Genetic transformation of switchgrass to produce polyhydroxybutyrate
University of Tennessee	<a href="http://web.bio.utk.edu">http://web.bio.utk.edu</a>	East	Genomics / Proteomics	Characterizing interactions between circulating proteins that have a role in regulating hemostasis and also in cancer.
University of Tennessee	<a href="http://web.bio.utk.edu">http://web.bio.utk.edu</a>	East	Molecular Biology / Biochemistry / Biophysics	Structure/function studies of enzymes that confer resistance to pathogenic bacteria; drug design
University of Tennessee	<a href="http://www.ceb.utk.edu">www.ceb.utk.edu</a>	East	Genomics / Proteomics	Transcriptional fusions for in vivo logic and cell based biocomputation hybrid silicon-biological integrated circuits and sensors bioenvironmental monitoring biosecurity Gene array analysis, functional genomics
University of Tennessee		East	Ag-Bio	Plant, animal, veterinary medical and human medical research.
University of Tennessee		East	Molecular Biology / Biochemistry / Biophysics	Work on macrolide toxins
University of Tennessee	<a href="http://www.che.utk.edu">www.che.utk.edu</a>	East	Diagnostics / Therapeutics	We are developing biosensors for aquatic toxicity and developing new bioprocesses for semi-commodity-scale chemical production
University of Tennessee	<a href="http://www.utk.eppserver">www.utk.eppserver</a>	East	Molecular Biology / Biochemistry / Biophysics	Developing new cultivars through gene discovery and transfer Relationships among plants -- DNA sequence and fingerprinting Relationships among fungi -- DNA sequence and fingerprinting
University of Tennessee	<a href="http://www.utk.edu">www.utk.edu</a>	East	Ag-Bio	Development of new diagnostic tests for infectious organisms and vaccine research

Institution	Web Site	Region	Research Field	Research Description
University of Tennessee		East	Molecular Biology / Biochemistry / Biophysics	Environmental Microbiology
University of Tennessee and GreenLight Biotech, LLC	<a href="http://www.psls.ag.utk.edu">www.psls.ag.utk.edu</a>	East	Ag-Bio	Plant transformation, genomics, algal biotechnology, production of phytosensors for sensing environmental contaminant and agents of mass destruction
University of Tennessee and VA Medical Center		West	Diagnostics / Therapeutics	Developing vaccines to prevent group A streptococcal infections and acute rheumatic fever and rheumatic heart disease, which is the leading cause of heart disease in children around the world
University of Tennessee Bowld Hospital	<a href="http://www.utbowld.org">www.utbowld.org</a>	West	Diagnostics / Therapeutics	UT Bowld Hospital is an acute-care hospital which operates as a unit of the University of Tennessee System. The hospital's role in research is only in a supportive role if hospital services are necessary to provide patient care in support of research efforts.
University of Tennessee College of Veterinary Medicine		East	Molecular Biology / Biochemistry / Biophysics	1. Intracellular signaling pathways in response to stress or cell quiescence. 2. Tobacco carcinogen in the early induction of breast cancer cells. 3. Molecular study of cytotoxic activity of anticancer agents.
University of Tennessee Health Science Center	<a href="http://www.utmem.edu/">http://www.utmem.edu/</a>	West	Molecular Biology / Biochemistry / Biophysics	Effects of alcohol on the brain
University of Tennessee Health Science Center		West	Diagnostics / Therapeutics	Identifying early genetic markers of acute pancreas allograft rejection
University of Tennessee Health Science Center		West	Diagnostics / Therapeutics	We are investigating mechanisms of lung injury and repair including agents that may protect the lung or promote healing.

Institution	Web Site	Region	Research Field	Research Description
University of Tennessee Health Science Center		West	Diagnostics / Therapeutics	We are trying to elucidate the physiological pathways involved in the initiation of innate immune responses to infectious agents. Our principal focus is on the afferent mechanisms of fever induction.
University of Tennessee Health Science Center		West	Genomics / Proteomics	Identifying mutations in the genome that affects the development and function of the nervous system
University of Tennessee Health Science Center		West	Diagnostics / Therapeutics	Insulin sensitizing agents and Insulin-stimulated signal transduction in human skeletal muscle. Gene chips, proteomics.
University of Tennessee Health Science Center	<a href="http://www.utmem.edu">http://www.utmem.edu</a>	West	Genomics / Proteomics	Comprehensive Biomedical Research Center
University of Tennessee Health Science Center		West	Diagnostics / Therapeutics	Gene therapy for eye diseases
University of Tennessee Health Science Center	<a href="http://www.utmem.edu/vision_core">www.utmem.edu/vision_core</a>	West	Genomics / Proteomics	CNS & Retina injury, Cell and Molecular Biology
University of Tennessee Health Science Center		West	Genomics / Proteomics	Comparative analysis of transcriptomes and proteomes of tissues from pre-diabetic mice
University of Tennessee Health Science Center	<a href="http://www.utmem.edu/vascular">www.utmem.edu/vascular</a>	West	Diagnostics / Therapeutics	Cardiovascular disease, thrombosis, restenosis, diagnosis of platelet defects, cancer metastasis
University of Tennessee Health Science Center		West	Genomics / Proteomics	Basic research in proteomics - method development and application to prostate diseases
University of Tennessee Health Science Center	<a href="http://www.utmem.edu">www.utmem.edu</a>	West	Genomics / Proteomics	Oxytocin effect on breast cancer and bone cancer and their ability to grow in bone. Characterization of proteins involved in normal and pathological calcifications.

Institution	Web Site	Region	Research Field	Research Description
University of Tennessee Health Science Center	<a href="http://molsci.utmem.edu">http://molsci.utmem.edu</a>	West	Molecular Biology / Biochemistry / Biophysics	Cellular and molecular basis for autoimmunity in systemic lupus erythematosus. Mechanisms for antibody induced disease pathogenesis in lupus. Immunological bases for racially determined differences in response to therapy in chronic hepatitis C infection.
University of Tennessee, Memphis	<a href="http://www.utmem.edu/pharmacology">www.utmem.edu/pharmacology</a>	West	Molecular Biology / Biochemistry / Biophysics	Determine molecular mechanism of action of alcohol on ion channel proteins
University of Tennessee, Memphis	<a href="http://www.utmem.edu/urology">www.utmem.edu/urology</a>	West	Genomics / Proteomics	Gene characterization, biomarkers of prostate cancer, gene therapy for prostate cancer; clinical trials
University of Tennessee, Memphis		West	Diagnostics / Therapeutics	Newer treatments of heart failure
University of Tennessee, Memphis		West	Molecular Biology / Biochemistry / Biophysics	Mechanisms involved in cell migration and cell death as they relate to polyamines and growth factors
Vanderbilt University	<a href="http://www.cuebiotech.com">www.cuebiotech.com</a>	Middle	Pharmaceuticals	cue BIOTech, Inc. (cue) is a biopharmaceutical company focused on creating a portfolio of novel therapeutics that target G-protein coupled receptors (GPCRs). GPCRs are physiologically significant receptors linked to numerous diseases including cardiovascular disease, mental illness, and cancer. Inhibiting the interaction between a GPCR and its G-protein blocks the ability of the receptor to initiate a signal in a cell. cue's approach to inhibition sets it apart from other drug discovery companies. Rather than block the ligand binding site, the company identifies compounds that block the intracellular G protein-binding site. cue's approach and proprietary high throughput screening platform are more effective than any existing methodologies and will result in small molecule lead compounds with <ul style="list-style-type: none"> <li>·Higher specificity</li> <li>· fewer side effects</li> <li>·Improved efficacy</li> <li>·Faster time to market</li> <li>·Higher probabilities of success in clinical trials</li> <li>·The ability to target diseases untreatable by existing methods.</li> </ul>
Vanderbilt University		Middle	Pharmaceuticals	Clinical trials pharmacologic studies of drug action brain imaging

Institution	Web Site	Region	Research Field	Research Description
Vanderbilt University		Middle	Pharmaceuticals	Identify genes responsible for congenital heart defects and blood vessel development as targets for drug development.
Vanderbilt University		Middle	Pharmaceuticals	Action of drugs on the two cyclooxygenase enzymes, both in vitro and in humans Regulation of Cyclooxygenase - 2 in colon cancer. Contribution of cyclooxygenases to Alzheimer's Disease Development of biomarkers for drug action in humans.
Vanderbilt University		Middle	Molecular Biology / Biochemistry / Biophysics	Free radical research
Vanderbilt University		Middle	Pharmaceuticals	Measure cellular signaling molecules that contribute to heart disease
Vanderbilt University		Middle	Pharmaceuticals	Structure, function and pharmacology of G-protein coupled receptors
Vanderbilt University	<a href="http://medschool.mc.vanderbilt.edu">http://medschool.mc.vanderbilt.edu</a>	Middle	Genomics / Proteomics	Structure-function studies of arrestin proteins that participate in regulation of G protein-coupled receptors.
Vanderbilt University	<a href="http://structbio.vanderbilt.edu">http://structbio.vanderbilt.edu</a>	Middle		
Vanderbilt University Medical Center		Middle	Diagnostics / Therapeutics	Basic research aimed at identifying novel treatment interventions for Parkinson's disease and schizophrenia.
Vanderbilt University Medical Center		Middle		The Vanderbilt University academic health center does more than \$200M of extramural support (direct dollars, not including federally funded indirect costs).

Institution	Web Site	Region	Research Field	Research Description
Vanderbilt University School of Medicine	<a href="http://medschool.mc.vanderbilt.edu/biochemistry">http://medschool.mc.vanderbilt.edu/biochemistry</a>	Middle	Molecular Biology / Biochemistry / Biophysics	Cancer biology: mechanism by which growth factors control cell proliferation.
Vanderbilt University School of Medicine	<a href="http://bret.mc.vanderbilt.edu">http://bret.mc.vanderbilt.edu</a>	Middle	Pharmaceuticals	Design of novel COx-2 inhibitors as possible treatments for arthritis.