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ANDERSON ECONOMIC GROUP

Life Sciences Industry in Michigan and the University Research Corridor

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I. Introduction and Summary of Findings

PURPOSE OF MICHIGAN'S UNIVERSITY RESEARCH CORRIDOR

The University Research Corridor (URC) is an alliance of Michigan's three largest academic institutions: Michigan State University, the University of Michigan, and Wayne State University. The purpose of this alliance is to accelerate economic development in Michigan by educating students, attracting talented workers, supporting innovation, and facilitating the transfer of technology to the private sector.

URC SPECIAL TOPIC REPORTS

In May of each year, the URC releases a report on a special topic that is important to Michigan's economy. This summer (July 2009) marks the ten year anniversary of the founding of the Life Sciences Corridor, a collaboration among the URC universities and the Van Andel Institute, where the state committed to invest $1 billion in life sciences research and development (R&D) over a 20-year period. This report analyzes how this industry has changed since the founding of the Life Sciences Corridor, and how URC activities—research and development, education, and collaboration with private industry—support the growth of the life sciences industry.

OVERVIEW OF REPORT AND METHODOLOGY

We begin this report by defining the life sciences industry. We use a rigorous definition of life sciences that builds upon our firm's previous work and includes industries whose work helps to improve the quality of human life through the research, development, and application of biological processes, tools, and advanced medical treatments. For this report we have updated our definition used in previous reports to include portions of agricultural and health care industries that are dedicated to R&D of new biological processes, methods, treatments, and technologies. We have not included in our definition primary health care services delivered in physician offices, clinics, or hospitals. Nor have we included the state's substantial production agriculture and forest industries, apart from R&D. See Table 1, "Definition of the Life Science Industry by Cluster," on page 8 and "Definition and Estimation Methodology" on page B-1.

We divide the life sciences industry into the following three clusters of activity:[1]

- *Biological Cluster*
  This cluster includes industries such as pharmaceutical and medical product manufacturing, chemical preparation and product manufacturing, and scientific research and development.
- *Agricultural Cluster*
  This cluster includes industries, and portions of industries, that develop methods and technologies to improve crop and animal production, animal product manufacturing, and veterinary science.
- *Medical Cluster*
  This cluster includes the share of hospital, medical school, and lab activities that are dedicated to research and development of new medical methods and technologies. Delivery of health care services is not included in our definition of life sciences.

1. These industry clusters are used to categorize private employment in the life sciences industry. Our analysis s of life sciences research, education, and outreach by the URC is related to these categories, but does not imply that the URC universities themselves engage in all activities included in the definition (e.g. product manufacturing).

KEY FINDINGS

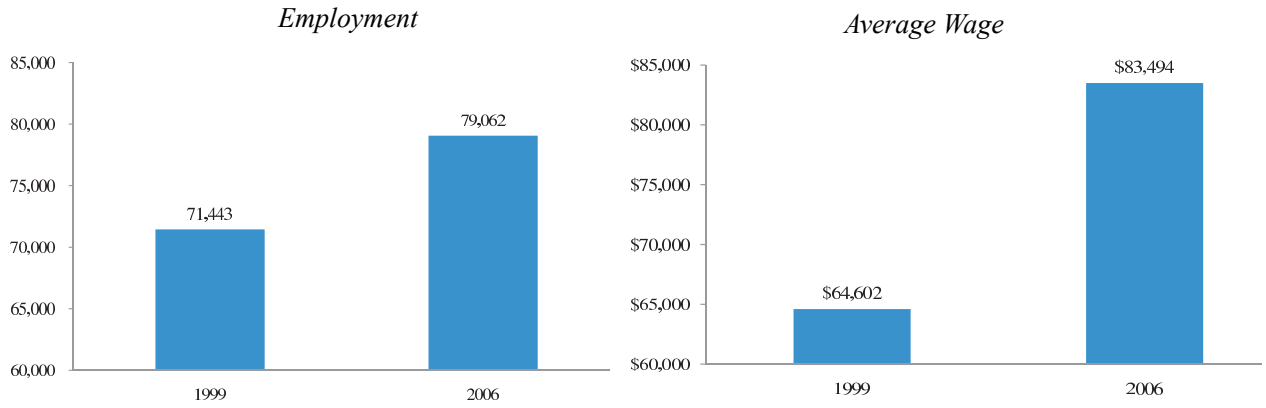
1. The Life Sciences Industry is Important in Michigan

In 2006 (the most recent for which data is available), the life sciences industry employed 79,062 people, accounting for 2.1% of all employment in Michigan. Due to the industry's higher average wages, the life sciences share of total payroll in the state is even greater than its employment share. In 2006, life sciences payroll was $6.6 billion, making up 4.4% of total state payroll. Life sciences employment and payroll make up a greater share of total industry employment in Michigan than in the U.S. as a whole. This is important as life sciences employment and average wages are growing. See "Life Sciences Industry: The Big Picture" on page 9.

2. Life Sciences Employment and Wages Have Grown Since 1999

Life sciences is a growing industry in Michigan. As shown in Figure 1 below, employment and average wages in this industry increased between 1999 and 2006. Employment in the life sciences industry increased 10.7% from 71,443 jobs in 1999 to 79,062 jobs in 2006 while Michigan's economy lost over 176,000 private sector jobs. Life sciences average annual wages increased 29.3% from $64,602 in 1999 to $83,494 in 2006. The growth in average wages is impressive by itself, but even more so when compared to the average wage growth across all industries in Michigan of only 11.2% to $39,666 in 2006. The number of life sciences jobs are growing in Michigan and they pay extremely well, $43,828 *more* than the average job in Michigan.

FIGURE 1. Employment and Average Wages in Life Sciences Industry

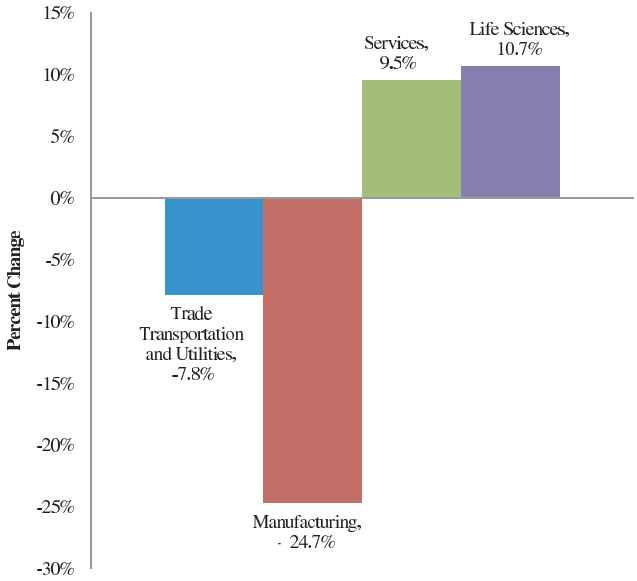


Base Data: U.S. Census Bureau, County Business Patterns, 1999 and 2006
Analysis: Anderson Economic Group, LLC

Life sciences employment gains are even more impressive when compared to employment changes in major industries between 1999 and 2006. During this seven-year time period manufacturing employment, which made up 16% of all Michigan private sector employment in 2006, fell by 24.7% while trade, transportation, and utilities employment (20% of total employment in 2006) fell 7.8%. Ser-

vice industries—including education, health care, professional services, accommodation, and food service—experienced employment gains during the seven-year time period, but by less than life sciences (9.5% compared to 10.7% for life sciences). See Figure 2 below.

FIGURE 2. Change in Employment by Major Industry in Michigan, 1999-2006



Base Data: U.S. Census Bureau, County Business Patterns, 1999 & 2006
Analysis: Anderson Economic Group, LLC

3. Michigan's URC Universities are Leaders in Life Sciences

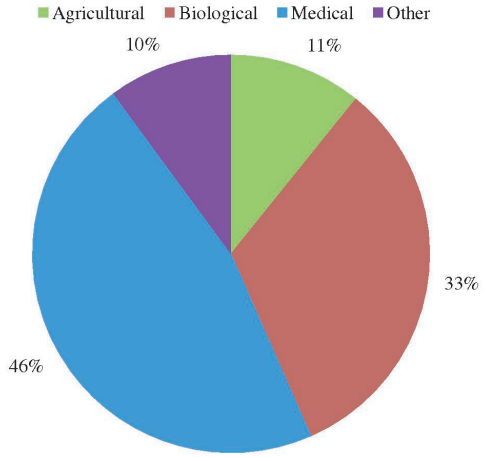
Michigan's URC universities are leaders in research and development in the life sciences and create a locus of expertise and activity for this growing industry. Of the seven peer university clusters with which the URC regularly compares itself, the URC is the third highest in share of total expenditures spent on life sciences. Peer university clusters include Duke, UNC, and NC State in North Carolina, Harvard MIT, and Tufts in Massachusetts, and UC San Francisco, UC Berkeley, and Stanford in Northern California.[2] The North Carolina cluster allocated the greatest share of R&D expenditures to life sciences of the seven university clusters (74% of total), with Northern California coming in second (66%) and Michigan third (64%).

In 2008, URC universities spent $887 million on life sciences research and development. Expenditures have grown 69% since the founding of the Life Sciences Corridor in 1999. Almost half of the life sciences portion (46%) went towards research in

2. See Caroline M. Sallee and Patrick L. Anderson, *Michigan's University Research Corridor: Second Annual Economic Impact Report*, commissioned by Michigan's University Research Corridor, September 17, 2008. Available at: http://www.AndersonEconomicGroup.com.

the medical cluster, as shown in Figure 3 on page 4. This is understandable, given that all three URC universities have medical schools.

FIGURE 3. URC University Life Sciences Expenditures by Cluster, 2008



Source: National Science Foundation, Survey of R&D Expenditures at Universities and Colleges, FY 2006-FY 2008

Analysis: Anderson Economic Group, LLC

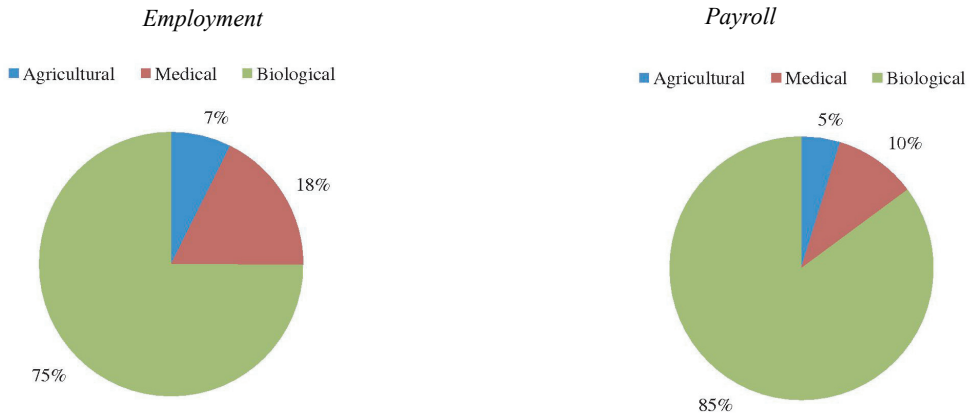
URC life sciences R&D brings considerable funding to Michigan. In 2008, 60% of funding came from federal sources, bringing $529.5 million in federal dollars to Michigan. This is money that was spent on salaries of researchers and to purchase supplies and equipment from firms in Michigan. The remaining 40% came from state financing, university fundraising efforts, and private donations. See "Funding Sources for Life Sciences Research" on page 18.

4. Most Life Sciences Employment is in the Biological Cluster

The majority of life sciences employment and payroll in Michigan is in the biological cluster, as shown in Figure 4 on page 5. In 2006, 75% of life sciences employment was in industries that we have identified as part of the biological cluster, while 85% of payroll was in this cluster. Within the biological cluster, the physical, engineering, and biological research industry (NAICS 541710), supported and developed in part by the URC, is by far the largest and most important in Michigan. The average wage for employees in this industry ($95,018) exceeds the life sciences industry average by $11,524.

URC universities have spent a significant portion of their life sciences research and development expenditures on biological research. In FY 2008, MSU and U-M each spent 31% of life sciences R&D on biological research while WSU spent 24%. For more information about URC life sciences expenditures see "Life Sciences Research and Development" on page 17.

FIGURE 4. Private Sector Employment and Payroll by Life Sciences Cluster, 2006



Base Data: U.S. Census Bureau, County Business Patterns, 2006
Analysis: Anderson Economic Group, LLC

5. Commercialization of URC Research is Creating Jobs

Research benefits the local community not only by bringing research funds to Michigan, but also by creating jobs when research spills over into commercial applications. Life sciences research in the URC has generated many new technologies with potential commercial value. Below we provide three examples, one from each of the URC universities. See "Commercialization of URC Life Sciences R&D" on page 24 for more examples.

Improving Health Care with Plants. Research by Michigan State University chemist Kevin Walker is paving the way for potentially cleaner, more efficient production of a cancer-fighting drug called paclitaxel, better known as the blockbuster drug Taxol. Walker's method of producing the drug employs natural enzymes that may allow pharmaceutical companies to reduce the steps involved in making Taxol, and reduce chemical by-products during production. This can lead to more effective health care treatment at a lower cost.

Commercial Success in Medical Imaging. University of Michigan professor of radiology Neal Clinthorne has used technology he developed at U-M to build smaller medical imaging equipment that is more affordable than other larger equipment on the market. Clinthorne's Ann Arbor company, Xoran, has developed a dental mini CT scanner that is making it possible for patients to make one stop for an initial exam, diagnostic scan, and start of their treatment. Xoran's products also allow physicians to add advanced diagnostic imaging capability right in their offices.

Advancing Sound Monitoring. Professor of engineering Yong Xu of Wayne State University is developing a stethoscope alternative that allows for better respiratory sound monitoring. Xu is developing a micro-sensor that is compact enough to be worn comfortably throughout the day, yet capable of picking up the weak vibrations

given off by breathing. This type of continuous respiratory monitoring could result in improved monitoring of patients under anaesthesia, better asthma management, and improved patient monitoring in intensive care units, nursing facilities, emergency medical services, and sleep studies.

6. Michigan's URC is Supporting Growing Industries and New Research in the Life Sciences

While some life sciences industries, such as pharmaceutical manufacturing and food product manufacturing and processing, have declined since 2006 (the most recent year for which we have data), other life sciences industries are growing. Through education and outreach, which we describe in more detail in "Education and Outreach" on page 19, the URC is supporting growing life sciences industries. For example, the URC has been able to establish programs that support the research and commercialization of biofuels, an industry where Michigan has a competitive advantage due to its high skill labor force, manufacturing base, and abundant natural resources. URC universities also conduct research in exciting and promising life sciences areas. One area that has seen recent growth is embryonic stem cell research, which we discuss in "Promising URC Life Sciences Research: Examples of Stem Cells Research" on page 23.

URC ANNUAL ECONOMIC IMPACT REPORTS

Each fall, the URC releases an annual report that quantifies the economic impact of the URC's activities on the state of Michigan's economy. This report provides Michigan residents with an assessment of how the URC universities are spending their time and money, and allows citizens to track the performance of the URC. Main findings from the 2008 *Annual Economic Impact Report* include:

- In FY 2007, Michigan's residents were over $13.3 billion richer due to the URC.
- The URC universities spent $1.38 billion on research and development in 2006, which is 94% of all R&D expenditures by universities in Michigan.
- The URC brought $855 million in federal research dollars to Michigan in 2006. This is money that paid salaries and bought supplies and equipment, fueling other economic activity in the state.
- 552,320 URC alumni living in Michigan earned $25.2 billion in salary and wages in 2007, or 13.3% of all wage and salary income in Michigan.
- On average, the URC received 126 patents and 122 licenses annually between 2002 and 2007. The URC helped cultivate an average of 15 start-up companies annually between 2002 and 2007.

The main findings from the 2008 *Annual Economic Impact Report* are presented in "At a Glance...The Economic Contributions of Michigan's Research Corridor" on page A-6.

ABOUT ANDERSON ECONOMIC GROUP

Anderson Economic Group is a research and consulting firm with expertise in public policy, economics, market research, and business valuation. AEG's past clients include state, city, and county governments, corporations, and nonprofit organizations. AEG has offices in East Lansing, Michigan and Chicago, Illinois. For more information see "About Anderson Economic Group" on page C-1.

II. Michigan's Life Sciences Industry

DEFINING THE INDUSTRY

In order to successfully conduct an industry analysis, we must first properly define the industry being studied. To do this for the life sciences industry, we have derived a definition using North American Industry Classification System (NAICS) codes—the classification system that the United States Census uses to report industry data. This definition provides a solid foundation for our analysis and makes possible the year-to-year data comparisons that illustrate the evolution of an industry.

Life Sciences Definition. We define the life sciences industry as businesses whose work helps to improve the quality of human life through the research, development, and application of biological processes, tools, and advanced medical treatments.[3] As shown in Table 1, "Definition of the Life Science Industry by Cluster," on page 8, we have divided the life sciences industry into three main clusters of activity—biological, agricultural, and medical. Our definition is comprehensive and includes parts of traditionally agricultural and medical industries whose activities fall under our definition of the life sciences.

For a detailed description of the methodology used to define the life sciences industry, see Appendix B on page B-1.

Consistency with Past Definitions. Our life sciences definition, as detailed by NAICS codes in Table 1 on page 8, is consistent with Anderson Economic Group's previous work in the life sciences, and with the definition used in *The Contribution of the Bioscience Industry to the Michigan Economy*, which was written by University of Michigan faculty and researchers and released in February of this year.[4] Nevertheless, our definition remains distinct from the aforementioned studies because we include the research components of the medical and health care industries in our definition. This addition accounts for the important life sciences research and development work being done in Michigan hospitals, medical schools, and universities. In addition, we only include portions of some of the agricultural industries that are included in the U-M study in their entirety. We apportioned these agricultural industries after reviewing the product codes and deciding that some of the activities do not fit within our definition of life sciences. We also include all payroll and employment in Physical, Engineering, and Biological Research industry

3. We first used this definition in *The Life Sciences Industry in Michigan: Employment, Economic, and Fiscal Contributions to the State's Economy* by Patrick L. Anderson and Scott D. Watkins (February 2004), available at: http://www.AndersonEconomicGroup.com.

4. Abel Feinstein, George A. Fulton, and Donald R. Grimes, *The Contributions of the Bioscience Industry to the Economy of Michigan Final Report*, prepared for Pharmaceutical Research and Manufacturers of America, February 2009. This study uses base data from the Bureau of Labor Statistics Quarterly Census of Employment and Wages. Missing data was estimated by the researchers using an algorithm developed by Donald Grimes. Portions of industries were estimated using the 2002 Census of Business, as well as product category distributions from the Census to estimate those industry codes that the Census of Business does not include.

(NAICS 541710), because it is our opinion that all activities in this industry belong in a comprehensive definition of life sciences. The U-M study only takes part (43.9%) of this industry, which is a large employer in Michigan. See "Definition and Estimation Methodology" on page B-1 for more information.

TABLE 1. Definition of the Life Science Industry by Cluster

NAICS Code	Percent of Industry Included	Description
Biological		
325411	100%	Medicinal and Botanical Manufacturing
325412	100%	Pharmaceutical and preparation manufacturing
325413	100%	In-vitro diagnostic substance manufacturing
325414	100%	Other biological product manufacturing
325991	100%	Custom Compounding of Purchased Resins
325992	100%	Photographic film, paper, and chemical manufacturing
325998	100%	All other miscellaneous chemical product manufacturing
339111	100%	Laboratory apparatus and furniture manufacturing
339112	100%	Surgical and medical instrument manufacturing
339113	100%	Surgical appliance and supplies manufacturing
339114	100%	Dental equipment and supplies manufacturing
339115	100%	Opthalmic goods manufacturing
339116	100%	Dental laboratories
334510	100%	Electromedical apparatus manufacturing
334516	100%	Analytical laboratory instrument manufacturing
334517	100%	Irradiation apparatus manufacturing
541380	4%	Testing laboratories
541710	100%	Physical, engineering, and biological research
Agricultural		
115112	1%	Soil Preparation, Planting, and Cultivating
115210	1%	Support Activities for Animal Production
115310	10%	Support Activities for Forestry
311221	45%	Wet corn milling
311222	1%	Soybean processing
311223	17%	Other oilseed processing
311313	6%	Beet Sugar Manufacturing
325110	100%	Petrochemical Manufacturing
325120	1%	Industrial Gas Manufacturing
325132	100%	Synthetic Organic Dye and Pigment manufacturing
325191	100%	Gum and Wood Chemical Manufacturing

Source: Anderson Economic Group, LLC

TABLE 1. Definition of the Life Science Industry by Cluster (Continued)

NAICS Code	Percent of Industry Included	Description
325192	100%	Cyclic Crude and Intermediate Manufacturing
325193	100%	Ethyl Alcohol Manufacturing
325199	100%	All other basic organic chemical manufacturing
325221	100%	Cellulosic organic fiber manufacturing
325311	100%	Nitrogenous fertilizer manufacturing
325312	100%	Phosphatic fertilizer manufacturing
325314	100%	Fertilizer (mixing only) manufacturing
325320	100%	Pesticide and other agricultural chemical manufacturing
541940	24%	Veterinary Services
Medical		
611310	4%	Colleges, Universities, and Professional Schools
621511	100%	Medical Laboratories
621512	100%	Diagnostic Imaging centers
622110	3%	General Medical and Surgical Hospitals
622210	3%	Psychiatric and Substance Abuse Hospitals
622310	3%	Specialty (except Psychiatric/Substance Abuse) Hospitals

Source: Anderson Economic Group, LLC

LIFE SCIENCES INDUSTRY: THE BIG PICTURE

The life sciences industry is an important part of the Michigan economy. As of 2006, the state's life sciences industry employed 79,062 people. More importantly, the life sciences industry is growing. Even between 1999 and 2006, when the Michigan economy lost over 176,000 jobs, life sciences industry employment increased by 10.7%.[5] More than 7,600 life sciences jobs were created in Michigan's life science industry during those years, as shown in Table 2 below and Figure 5 on page 10.

TABLE 2. Employment, Payroll, and Average Wage in Life Sciences Industry

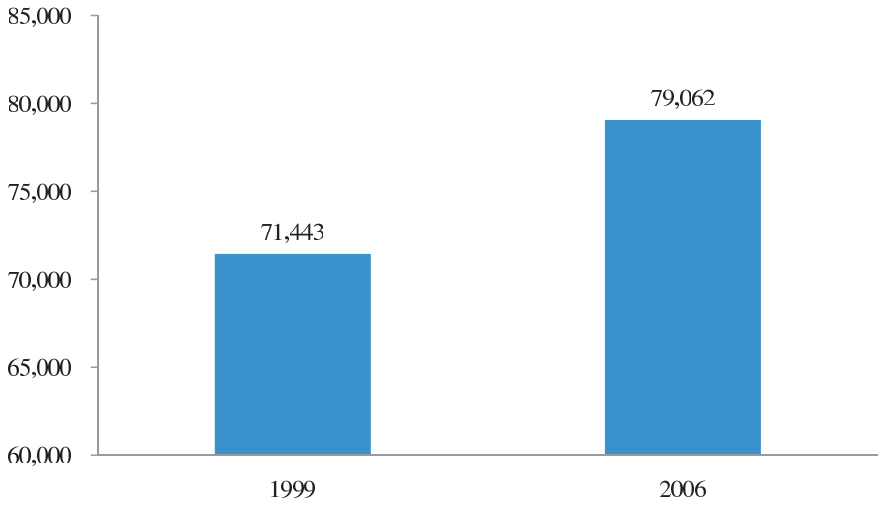
	Employment	Total Payroll ($1,000)	Average Wage
1999	71,443	$4,615,374	$64,602
2006	79,062	$6,601,247	$83,494
Growth 1999-2006	10.7%	43.0%	29.2%

Source: Anderson Economic Group
Data: U.S. Census Bureau, County Business Patterns

5. U.S. Census Bureau County Business Pattern data for Michigan reports an employment decrease of 176,763 jobs between 1999 and 2006.

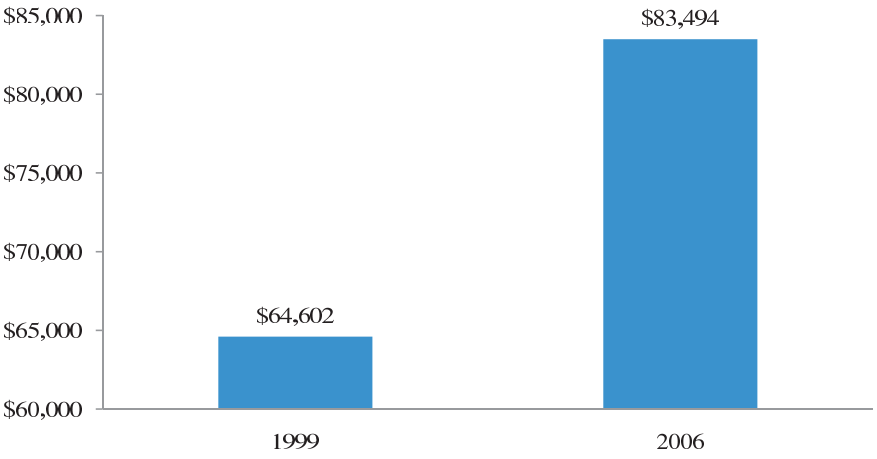
Life sciences jobs pay very well in Michigan. In 2006, the industry's payroll totaled more than $6.6 billion for an average wage of $83,494. Between 1999 and 2006 average wages in the industry increased 29.2%, adding almost $2 billion in annual payroll in Michigan. See Figure 6 on page 10.

FIGURE 5. Life Science Industry Employment in Michigan



Base Data Source: U.S. Census Bureau, County Business Patterns Data, 1999 & 2006
Analysis: Anderson Economic Group, LLC

FIGURE 6. Average Annual Wage in Michigan's Life Science Industry



Base Data Source: U.S. Census Bureau, County Business Patterns Data, 1999 & 2006
Analysis: Anderson Economic Group, LLC

COMPARISON WITH U.S. LIFE SCIENCES INDUSTRY

When compared to the United States average, more private sector employment comes from the life sciences in Michigan than for the country as a whole. As shown in Table 3 on page 11, employment in the life sciences industry made up 2.1% of total employment in Michigan compared to 1.7% nationwide in 2006. This trend holds for payroll as well, with 4.4% of all payroll in Michigan coming from the life sciences compared to 2.8% of all payroll in the United States resulting from the life sciences industry.

TABLE 3. Life Sciences Industry Share of Employment and Payroll (2006)

	State of Michigan		United States	
	Employment	**Payroll**	**Employment**	**Payroll**
1999	1.8%	3.3%	1.6%	2.6%
2006	2.1%	4.4%	1.7%	2.8%

Base Data: U.S. Census Bureau, County Business Patterns
Analysis: Anderson Economic Group, LLC

These measures of employment and payroll demonstrate Michigan's strength in the life sciences as well as the industry's significance to Michigan's economy both now and in the future. Considering the opportunities for industry expansion created by university research and spin-off companies in the state, as well as the trend towards industry growth demonstrated in past years, the life science industry's importance in Michigan will likely increase in years to come.

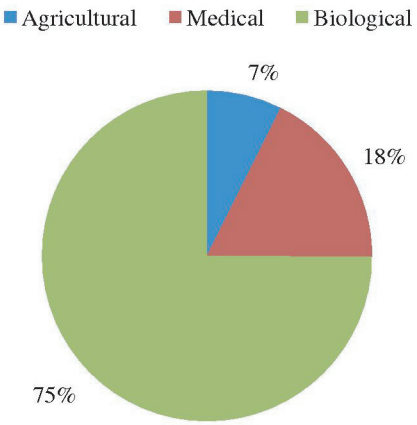
LIFE SCIENCES INDUSTRY CLUSTERS

As noted earlier, we have defined the life sciences industry by NAICS codes, which classify businesses by their primary activity. In total, we identified 44 NAICS codes that should be included in the life sciences industry's definition. We then organized these NAICS codes into three distinct activity clusters:

- *Biological Cluster*
  This cluster includes industries such as pharmaceutical and medical product manufacturing, chemical preparation and product manufacturing, and scientific research and development.
- *Agricultural Cluster*
  This cluster includes industries, and portions of industries, that develop methods and technologies to improve crop and animal production, animal product manufacturing, and veterinary science.
- *Medical Cluster*
  This cluster includes the share of hospital, medical school, and lab activities that are dedicated to research and development of new medical methods and technologies. Delivery of health care services is not included in our definition of life sciences.

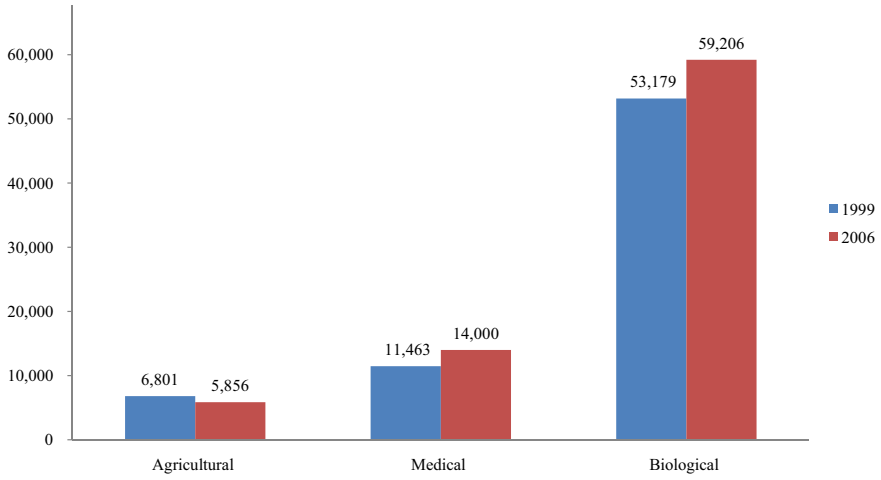
The composition of employment in Michigan's life sciences industry is shown by cluster in Figure 7 on page 12. The biological cluster is Michigan's largest, accounting for nearly 75% of total industry employment in 2006. The medical cluster accounts for 18%, and the agricultural cluster 7% of life sciences employment. As shown in Figure 8 on page 12, both the biological and medical clusters have grown since 1999.

FIGURE 7. Michigan's Life Sciences Industry Employment, by Cluster (2006)



Source: U.S. Census Bureau, County Business Patterns, 2006
Analysis: Anderson Economic Group, LLC

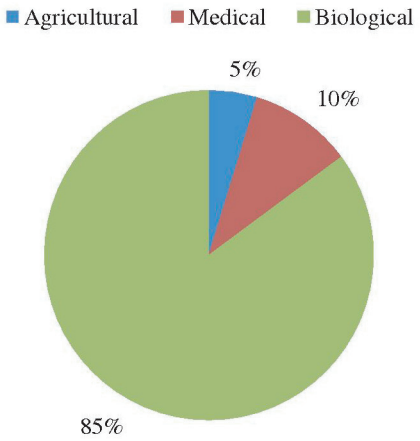
FIGURE 8. Michigan Employment by Life Science Industry Cluster



Source: U.S. Census Bureau, County Business Patterns, 2006
Analysis: Anderson Economic Group, LLC

The percentage of total industry payroll attributable to each cluster closely tracks cluster employment levels, with the biological cluster representing the largest percentage of annual industry payroll. As shown in Figure 9 on page 13, however, higher average wages in the biological cluster results in this cluster having a greater share of total payroll than employment; the biological cluster makes up 85% of total payroll and only 75% of total employment.

FIGURE 9. Michigan's Life Sciences Industry Payroll, by Cluster (2006)



Source: U.S. Census Bureau, County Business Patterns, 2006
Analysis: Anderson Economic Group, LLC

Biological Cluster. The biological cluster includes 18 NAICS codes, as shown in Table 1 on page 8. It is comprised of those sectors engaging in activities such as pharmaceutical and medical product manufacturing, chemical preparation and product manufacturing, and scientific research and development.

The biological cluster employed 59,206 people in 2006, or 75% of the state's life science industry employment. This underscores the continued importance of the traditional life sciences to Michigan's economy and the state's manufacturing strength. Between 1999 and 2006, the most recent year for which data is available, Michigan's biological cluster grew 11.3% from 53,179 jobs in 1999 to 59,206 jobs in 2006. Additionally, the average wage for the industry cluster increased by $20,912 between 1999 and 2006, as shown in Table 4 on page 14.

Within the biological cluster, the Physical, Engineering, and Biological Research industry (NAICS 541710) is by far the largest and most important in Michigan. The industry, which, also includes biotechnology, accounted for more than 48% of Michigan's total life sciences employment in 2006. The average wage for employees in the Physical, Engineering, and Biological Research industry ($115,960) exceeds the life sciences industry average by $32,470. Physical, Engineering, and Biological Research is the most important sector to the biological cluster in terms of payroll as well, accounting for more than 67% of the life science industry's annual payroll in the state.

See Table 4 below for more information on employment and payroll in Michigan's biological cluster.

TABLE 4. Employment, Payroll, and Average Wage—Biological Cluster

	Employment	Total Payroll ($1,000)	Average Wage
1999	53,179	$3,940,969	$74,108
2006	59,206	$5,625,650	$95,020
Growth 1999-2006	11.3%	42.7%	28.2%

Source: Anderson Economic Group, LLC

Data: U.S. Census Bureau, County Business Patterns

Agricultural Cluster. Businesses included in the agricultural cluster of the life sciences industry definition develop methods and technologies to improve crop and animal production, animal product manufacturing, and veterinary science. The cluster captures the research and development advances being made in agricultural science, and in the manufacturing of new technologies designed to advance the agriculture industry. Specifically, the definition includes those businesses engaged in activities classified under the agricultural cluster's NAICS codes, which are listed in Table 1 on page 8.

In total, Michigan's agricultural cluster employed 5,856 people in 2006, or 7.4% of the state's life sciences industry, and accounted for 4.7% of industry payroll in the state. The cluster experienced a decline in employment between 1999 and 2006. While employment in the agricultural cluster decreased by 13.9%, however, total payroll increased by 13.3% between 1999 and 2006, as shown in Table 5 below.

Within Michigan's agricultural cluster, Other Basic Organic Chemical Manufacturing (NAICS 325199) was the largest sector as of 2006, accounting for 49% of the cluster's employment and 67% of the agricultural cluster's payroll. See also Appendix A-2 on page A-3.

TABLE 5. Employment, Payroll, and Average Wage—Agricultural Cluster

	Employment	Total Payroll (1,000s)	Average Wage
1999	6,801	$272,183	$40,021
2006	5,856	$308,452	$52,672
Change 1999-2006	-13.9%	13.3%	31.6%

Source: Anderson Economic Group, LLC
Data: U.S. Census Bureau, County Business Patterns

Medical Cluster. The medical cluster includes the percentage of hospital, medical school, and lab activity that is dedicated to research and development of new medicinal methods, technologies and solutions. This important component of the life sciences industry has often been left out of other industry analyses, but, as it

accounts for the important medical research contributing to the life sciences industry, it is an integral part of this comprehensive definition.

The life science industry's medical cluster employed 14,000 people in Michigan in 2006, and generated more than $667 million in total payroll. Despite the economic recession, employment and total payroll in the cluster increased substantially between 1999 and 2006. During that time period, medical cluster employment increased by 22% and total payroll increased by a substantial 66%. Further, jobs created by the medial cluster are high-wage, with average employee wages above $47,000 annually in 2006. See Table 6 for more details on employment, payroll, and average wages in the cluster.

TABLE 6. Employment Payroll and Average Wage—Medical Cluster

	Employment	Total Payroll (1,000s)	Average Wage
1999	11,463	$402,222	$35,087
2006	14,000	$667,153	$47,650
Growth 1999-2006	22.1%	65.9%	35.8%

Source: Anderson Economic Group, LLC
Data: US Census Bureau, County Business Patterns

Within the medical cluster, the General Medical and Surgical Hospitals sector (NAICS 622110), followed closely by the Medical Laboratories and Diagnostic Imaging Center sectors (NAICS 621511 and 621512 respectively) accounted for the largest percentages of cluster employment and payroll. The percentage of the General Medical and Surgical Hospital sector included in the life sciences industry definition made up approximately 40% of the medical cluster's total employment and nearly 36% of the cluster's total payroll. See Appendix A-2 on page A-3.

Between 1999 and 2006, the percentage of Michigan's life sciences industry employment and payroll attributable to the medical cluster increased. By 2006, the medical cluster made up nearly 18% of Michigan's total industry employment, as well as more than 10% of total industry payroll.

INDUSTRY TRENDS SINCE 2006

Since 2006, Michigan has seen employment declines in many industries, particularly in manufacturing. According to data from Michigan's Department of Energy, Labor and Economic Growth (DELEG), manufacturing employment declined by 26% between January 2006 and March 2009.[6] We have included many manufacturing industries in our definition of life sciences, particularly in the agriculture and biology clusters. We would expect to see declines in employment in many of these clusters' industries since 2006. One very public example is the state's loss of phar-

6. See State of Michigan Department of Energy, Labor & Economic Growth, Bureau of Labor market Information & Strategic Initiatives, Current Employment Statistics Section at http://www.milmi.org/.

maceutical manufacturing with Pfizer Inc.'s pullout of Michigan, which eliminated jobs in Holland, Kalamazoo and Ann Arbor between 2003 and 2007.

Despite these losses, however, Michigan's life sciences industry has shown signs of substantial growth and promise for continued expansion in the future. Areas of promise include new agricultural industries, particularly in the area of biofuels. We discuss Michigan's State University's support of agricultural life sciences industries in "Education and Outreach" on page 19. Another area of growth is Michigan's medical and health care industries. Using the same data from DELEG, employment in health care and social assistance has increased 6% since January 2006. As we explain in "Promising URC Life Sciences Research: Examples of Stem Cells Research" on page 23, stem cells research is one example of growth in the life sciences in Michigan.

III. URC Support for Michigan's Life Sciences Industry

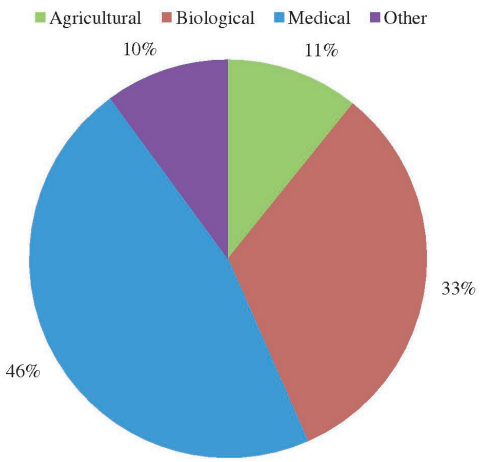
The URC universities are leaders in research and development in the life sciences and create within Michigan a locus of expertise and activity for this growing industry.

LIFE SCIENCES RESEARCH AND DEVELOPMENT

URC Research Expenditures

One of the ways that the URC universities support a thriving life sciences industry in Michigan is through its tremendous investment in research and development. Since the founding of the Life Sciences Corridor in 1999, URC universities expenditures on life sciences research and development have increased 69% from $523.4 million in 1999 to $887.8 million in 2008. The URC universities spent 60% of their total science and engineering R&D expenditures on life sciences in 2008—up from 54% in 1999.[7] Within life sciences, the URC universities spend the most on medical research and development, as shown in Figure 10 on page 17. URC universities spent $289.6 million on biological cluster R&D (33% of total), $95.8 million on agricultural R&D (11% of total), and more than $412.8 million on research and development in the medical cluster (46% of total).

FIGURE 10. URC University Life Science Expenditures by Cluster, 2008

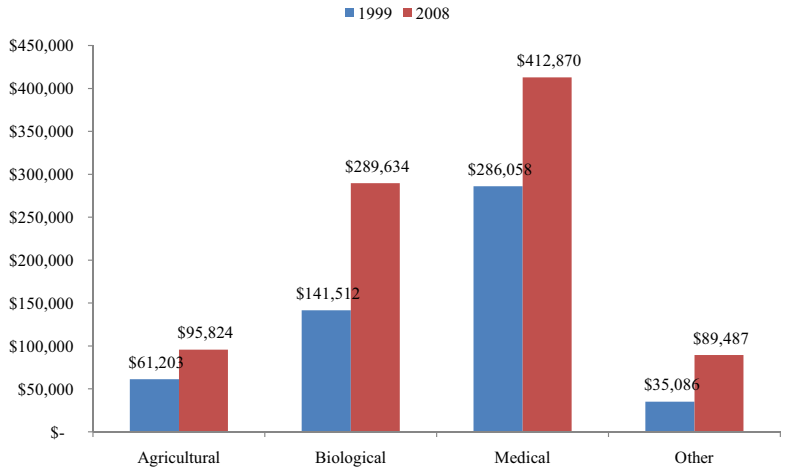


Base Data: National Science Foundation, Survey of R&D Expenditures at Universities at Universities and Colleges, FY 2006-2008
Analysis: Anderson Economic Group, LLC

7. University life sciences expenditure data comes from the National Science Foundation (NSF) Survey of Research and Development Expenditures by Universities and Colleges. The survey breaks down life science expenditures into three specific categories—biological, agricultural, and medical. Though these categories are defined by the National Center for Education Statistic classifications, these categories map nicely to our industry clusters of the same names. See Appendix A-4 on page A-5.

In 1999 and 2008 URC universities spent a greater portion of their R&D expenditures on activities in the medical cluster than in the other clusters, as shown in Figure 11 on page 18. Between 1999 and 2008, expenditures on medical R&D in the URC increased 44%. However, during this time period expenditures on activities in the biological cluster more than doubled (an increase of 105%). As shown in the previous section, most private sector employment in Michigan's life science industry is in the biological cluster. URC universities are supporting these private sector activities, and have spent a significant portion of their life sciences research and development budget funding biological research. Michigan State University, for example, spent 44% of its total life science R&D expenditures on the biological cluster, while the University of Michigan and Wayne State University dedicated 31% and 24% of their total life science expenditures, respectively, on biological cluster activities.

FIGURE 11. Michigan's URC Expenditures on Life Sciences R&D by Category, 1999 & 2008



Base Data: National Science Foundation, Survey of R&D Expenditures at Universities at Universities and Colleges, FY 1999
Analysis: Anderson Economic Group, LLC
Data Note: Expenditures for MSU are estimated for 1999 based on analysis of 2000 life sciences expenditures.

Funding Sources for Life Sciences Research

Each university uses private, industry, federal, and state resources to produce high quality research in areas of its strength. The funding dedicated to life sciences research by URC universities comes from numerous sources. In 2008, 60% of the life sciences research funding used by URC universities came from federal sources, bringing $529.5 million to the state. A greater portion of life sciences R&D is being funded by the federal government since 1999 when 53% of expenditures were funded by federal sources. Federal funding coming into the state paid for salaries of researchers and staff at each of the universities and was used to purchase supplies and equipment, much of which comes from firms in the state. The remaining 40%

come from state financing, university fundraising efforts, and private donations. The URC's important work in the life sciences depended on local sources for more than $358.3 million dollars in 2008.

EDUCATION AND OUTREACH

The wide range of education and outreach programs dedicated to the life sciences demonstrate the commitment of URC universities to development of this industry in Michigan. These programs educate and prepare students for careers in life sciences industries; foster the commercialization of research in the form of private, spin-off companies in Michigan; and support existing and new industries with research and expertise. Each of the URC universities touch Michigan's workforce, industry, and communities with their own set of strengths. We present examples of URC activities by life sciences cluster.

Biological Cluster Activities

Pharmaceutical manufacturing is an industry that has suffered employment losses since 2006. Beginning in 2007 closure of Pfizer facilities in Ann Arbor and Kalamazoo resulted in many private sector employment losses in this industry. However, the URC universities have stepped in to transform abandoned space into productive R&D and commercialization centers.

Pfizer Facility in Ann Arbor. After a period of due diligence, which ended on May 18 of this year, the University of Michigan has finalized its purchase of what was Pfizer Inc.'s Ann Arbor facility. Taking the facility's closure as an opportunity for expansion of the university's research, U-M plans to house its ever-expanding research efforts on the property, as health, biomedical sciences, and other disciplines have been restricted by lack of research space. The facility will also create opportunities for increased collaboration and partnership with industry in the region.

In total, the University of Michigan estimates that the 2 million square feet of laboratory and administrative space purchased will increase the University's research capacity by 10% and create 2,000-3,000 high quality jobs in the coming decade.[8]

Pfizer Facility in Holland, Michigan. Pfizer, Inc. donated its Holland, Michigan facility to Michigan State University, who is repurposing the space for use as the MSU Bioeconomy Institute. The Bioeconomy Institute is dedicated to exploring the economic potential of new biomaterials, specifically chemicals and biofuels. Though the facility opened only recently, it has already begun providing dislocated worker training. The facility will soon host private sector research and pilot plant scale-ups by early-stage entrepreneurs and researchers from Michigan corporations, in addition to Michigan State University's own research, education, and outreach efforts.

8. Letter to University of Michigan faculty and staff dated May 14, 2009 from Provost Teresa A. Sullivan.

The facility, which includes labs, an auditorium, and a chemical pilot plant, is currently renting space to AFID Therapeutics, Inc—a MSU faculty entrepreneur's company, which conducts research and development on complex carbohydrates derived from environmentally friendly and abundant non-food biomass sources. Michigan State University is actively recruiting additional tenants for the facility and seeks to encourage additional university research spin-off companies, while also nurturing non-university life science businesses, as well as partnership with major Michigan manufacturers.

Agricultural Cluster Activities

Michigan State University has created numerous outreach programs to encourage the commercialization of academic research in the life sciences. The Michigan Agricultural Experiment Station (MAES), for example, was created to generate knowledge through research that will be used to help Michigan's agriculture, natural resources, and rural communities, while fostering environmental stewardship.[9] The MAES is supported by the research of more than 300 scientists across six MSU colleges: Agriculture and Natural Resources, Communication Arts and Sciences, Engineering, Natural Science, Social Science, and Veterinary Medicine. In addition to its East Lansing facility, the MAES operates 14 field stations across the state, and has focused its research efforts on the issues found to be most pressing to Michigan, including improving the state's economy.

In addition to the MAES's targeted research, the MSU Extension, founded to "help people improve their lives through an educational process that applies knowledge to critical needs, issues, and opportunities," has successfully helped to strengthen Michigan's life sciences industry. For example, MSU Extension provided information and research that led to the founding of Great Lakes Ethanol, a manufacturing facility established by more than 300 farmer members that has been designed to produce 60 million gallons of ethanol annually.

As described previously in this section, employment in the life sciences agricultural cluster declined between 1999 and 2006. Most of this decline came from manufacturing industries within this cluster. MSU is assisting many agricultural businesses in the state and helping to re-invent dying industries with new products, such as biofuels.

MSU established the Product Center for Agriculture and Natural Resources (ANR) in Spring, 2003 with funds from the Michigan Agricultural Experiment Station and Michigan State University Extension to improve economic opportunities in the Michigan agriculture, food and natural resource sectors. The Product Center helps develop and commercialize high value, consumer-responsive products and businesses in the agriculture and natural resource sectors.

9. Michigan State University (website), "MAES Research: About the MAES," 16 March 2009.

Since its founding, the Product Center's activities have led to 127 known new businesses and business expansions in Michigan. Additionally, MSU estimates the Product Center's activities have helped create 606 new jobs and retained 348, while increasing annual sales by $193.6 million in the first year of its operation. In its April 2009 newsletter, the Product Center reported assisting 209 clients with business concept development in 2008, resulting in 29 venture launches statewide. Below we provide two examples of businesses the Product Center has helped in Michigan.

Sawmill Turns Waste Into Value. The Product Center provided assistance to brothers Gerald and Russell Maeder, owners of Maeder Brothers Sawmill in Weidman, Michigan. Maeder Brothers Sawmill started producing log homes twenty-five years ago and custom built more than 30 annually in its heyday. Because of competition and the contracting economy, however, only a fraction of those homes are built today. The business had also sold its wood chips and some sawdust to pulp mills in various parts of the state, but as the paper industry left Michigan and the pulp mills shut down, the Maeder's found they were building inventories of chips and sawdust. Though they continued to sell some sawdust to livestock producers, they need to find some way to move our excess chips and sawdust.

In order to adapt to the current business environment, the family decided to start a new wood pellet business in November 2005. A pellet mill is a facility that presses wood chips, sawdust, and other biomass into very dense small, cylindrical pellets that can be burned in properly-designed home stoves and furnaces, as well as used as fuel for large industrial boilers. After building their plant, the Maeder's started production in November 2006. The MSU Product Center, worked with them to develop their business plan, create a business logo, marketing brochures, labeling and bag design, complete a legal review, and develop their website. In 2008, orders throughout the summer exceeded production capacity as the number of stoves have grown and buyers experienced shortages of wood pellets. The Maeder's firm was running "24/7".

Medical Cluster Activities

The University of Michigan's strengths in education and outreach are the education, research, and employment in its medical school programs and health system, which are among the best in the nation. The U-M medical school ranks 11th in the nation according to *U.S. News and World Report's Medical School* rankings for 2009, as well as 7th in the nation for National Institute of Health funding totals.[10] While U-M's medical school prepares graduates for careers in the life sciences, the University of Michigan also operates the only URC run hospital through its University of Michigan Health System—a major employer in Michigan's life sciences industry.

10. The *U.S. News and World* report ranks medical schools overall and according to various specialities in its Best Medical Schools release. For the full results of the latest rankings, as well as an explanation of the methodology used, see the U.S. News and World Report website at http://grad-schools.usnews.rankingsandreviews.com/best-graduate-schools/top-medical-schools/research-rankings.

The University of Michigan Health System consists of University Hospital, C.S. Mott Children's Hospital, Women's Hospital, 30 health centers, 120 outpatient clinics, the University of Michigan Medical School, and Michigan Health Corporation. In total, the University of Michigan Health System employed 18,298 faculty and staff in 2008.[11]

The University of Michigan also has the URC's only school of dentistry, which includes a large clinical practice. During the 2006-07 academic year, 79,618 patients were treated in Ann Arbor, 20% of whom were Medicaid patients. This makes U-M one of the largest providers of dental treatment for patients with Medicaid benefits, having provided $4.3 million in Medicaid services.[12]

Michigan State University is expanding its emphasis on medical research and education through the development of a new medical campus in Grand Rapids that will complement the university's existing medical school program in East Lansing and an osteopathic medical program in southeast Michigan. MSU is also home to the state's only College of Veterinary Medicine.

Wayne State makes a significant contribution to the Michigan life sciences industry through its medical education programs in the state's largest city. Enrollment at Wayne State's medical school has been increasing steadily over the past decade, with the number of graduates increasing by more than 30% from 2001-2005. A high percentage of Wayne State University medical school graduates stay in Michigan for their graduate medical education (GME). In 2005, 65% of WSU graduates remained in Michigan for their GME.[13] As shown by surveys of physicians by the Association of American Medical Colleges Center for Workforce Studies, physicians who complete their GME in a state are more likely to remain in that state and practice medicine.

Wayne State University's contribution to medical education will be enhanced further when it completes the Mazurek Medical Education Commons building in June of this year. Named for a distinguished WSU alumnus and physician, the building will be LEED certified, signifying that it meets high standards in rating categories such as energy efficiency, water efficiency, CO2 emissions, and indoor environmental quality set by the U.S. Green Building Council. The Mazurek Medical Education Commons is designed to facilitate interdisciplinary medical education, incorporating learning in physics, bioengineering, biomedical research, and medical specialties. The learning environment will also offer medical training technologies such as virtual reality devices and human patient simulators.

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11. University of Michigan Health System (website), "About UMHS: Facts and Figures," 2009.
12. See Caroline M. Sallee and Patrick L. Anderson, *Michigan's University Research Corridor: First Annual Economic Impact Report*, commissioned by Michigan's University Research Corridor, October 17, 2007. Available at: http://www.AndersonEconomicGroup.com.
13. See Caroline M. Sallee and Patrick L. Anderson, *Michigan's University Research Corridor: First Annual Economic Impact Report*, commissioned by Michigan's University Research Corridor, October 17, 2007. Available at: http://www.AndersonEconomicGroup.com.

PROMISING URC LIFE SCIENCES RESEARCH: EXAMPLES OF STEM CELLS RESEARCH

URC universities conduct research in exciting and promising life sciences areas. One area that has seen recent growth is stem cell research. In November 2008 Michigan voters passed Proposal 2, which explicitly allows researchers to harvest embryonic stem cells from otherwise-discarded embryos created in fertility treatments. While explicitly prohibiting human cloning, Article I, §27 of the State of Michigan's Constitution states that use of these embryos for research purposes is allowed in order to, "ensure that Michigan citizens have access to stem cell therapies and cures, and to ensure that physicians and researchers can conduct the most promising forms of medical research in this state, and that all such research is conducted safely and ethically."

Research at Wayne State University. The laboratory run by Dr. Carol Brenner at Wayne State University is part of the new Michigan stem cell consortium, which plans to work with other University Research Corridor partners. Dr. Brenner and her staff, who are long-time leaders in the study of monkey embryology and stem cell biology, are engaged in collaborative projects with other laboratories at WSU to study human embryonic stem cells. The main focus of the laboratory has been to characterize the role of mitochondria, which are a type of cellular "machinery" that generate energy in every cell in the body, in reproduction in monkey embryos and embryonic stem cells. Brenner's lab is working with a special type of human embryonic stem cells (called trophoblast stem cells) that may help researchers understand placental formation and, ultimately, improve maternal and fetal health.

Dr. Brenner's lab is also using stem cell technology to study dysfunction in the cells of patients with neurological diseases. The research starts with samples of a certain type of cell (called fibroblasts) from patients with neurological diseases such as spinal muscular atrophy (SMA) and Charcot-Marie-Tooth disease, which is one of the most common inherited neurological disorders, affecting nearly 1 in 2,500 people in the United States. The researchers can then create stem cell lines by reprogramming the cells. These disease-derived stem cells are then used to study the role played by dysfunctional mitochondria in neurological diseases.

The A. Alfred Taubman Medical Research Institute Consortium for Stem Cell Therapies at the University of Michigan. The University of Michigan has also increased its stem cell research efforts. In March, U-M announced the formation of a consortium to create new embryonic stem cell lines that will aid the search for disease treatments and cures. The A. Alfred Taubman Medical Research Institute Consortium for Stem Cell Therapies is the first major embryonic stem cell research program launched in Michigan since the passage of Proposal 2. The founding of this center—combined with the recent state law change and the executive order signed by President Obama easing restrictions on federal funding for embryonic stem cell research—is expected to transform embryonic stem cell research. The consortium will develop new embryonic stem cell lines for U-M researchers and clinicians. In addition, collaborations are being negotiated between U-M and its University Research Corridor partners, Michigan State University and Wayne State University. Collaborations are also in the works with Oakland University, U-M Dearborn and Case Western Reserve University in Ohio.

Research at Michigan State University: Cellular Reprogramming Lab. MSU experts have developed novel techniques to isolate kidney, breast, pancreatic, liver and gastric adult stem cells from human and canine tissues. Currently, the MSU Cellular Reprogramming Laboratory focuses on analyzing cells at the molecular level to understand how normal cells can be turned back into stem cells through introduction of genes or gene products, by nuclear transfer, or by parthenogenesis (cell development without normal fertilization).

Treatment with this type of stem cells, called autologous stem cells (which are derived from the patient's own normal cells), is an important line of research because not everyone can be treated with embryonic stem cells. For example, only about one-third of Caucasians could be matched with embryonic stem cells, if a national stem cell bank were to be developed.

Researchers from MSU are already working with the Spanish government and other scientists in Europe to set up pre-clinical trials under the guidance of EMEA (Europe's version of the FDA). This research would use autologous stem cell lines developed and produced at MSU. Furthermore, the research will take advantage of MSU's strengths in working with animal models of human and animal diseases for pre-clinical trials.[14]

COMMERCIALIZATION OF URC LIFE SCIENCES R&D

Research benefits the local community not only by bringing research funds to Michigan, but also by creating jobs when research spills over into commercial applications. For example, between 2002 and 2007, the URC helped start an average of 15 start-up companies annually for the commercialization of research.[15] Life sciences R&D in the URC has generated many new technologies with commercial value. Below we provide several examples from each of the URC universities.

Improving Cellulosic Biofuels. A federal grant of $1.4 million from the Department of Energy is allowing Michigan State University to establish a new biofuel research program at the university's Upper Peninsula Tree Improvement Center in Escanaba. With 19.3 million acres of forestland, Michigan is rich with forest resources. Cellulose, a compound that is one of the basic building blocks of plants, and which is abundant in wood, is a potential source of renewable fuels that does not compete with food demand, as corn-based ethanol does. New federal funding will allow MSU and Michigan Technological University (MTU) scientists to research and develop ways to turn Michigan's natural resources into a sustainable and commercially viable renewable fuel source. This funding will allow the universities to expand the work they have already begun and increase the scope of their work to the entire state.

14. More on MSU's stem cell research at http://special.news.msu.edu/stemcell/

15. See Caroline M. Sallee and Patrick L. Anderson, *Michigan University Research Corridor: Second Annual Economic Impact Report*, September 17, 2008.

To maximize the economic impact of their new effort, MSU and MTU hosted a biofuels summit in Escanaba in 2008, attended by 50 representatives of businesses from all aspects of the forest-based bioeconomy, as well as state and local government agencies. The goal of the summit was to identify key questions the universities should address in three priority areas: feedstock production, feedstock supply chains, and feedstock conversion systems and integration. The summit also furthered the MSU-Sweden bioeconomy relationship by featuring presentations from four Swedish bioenergy researchers, who explained Sweden's transition to renewable fuels. Michigan Agricultural Experiment Station researchers believe that Michigan can use Sweden as a model when developing the state's forest-based bioeconomy.

Improving Health Care with Plants. Research by Michigan State University chemist Kevin Walker is paving the way for potentially cleaner, more efficient production of a cancer-fighting drug called paclitaxel, better known as the blockbuster drug Taxol. Taxol is used to treat many cancers, including breast, uterine, and ovarian cancers.[16]

First isolated from the bark of the Pacific yew in 1967, paclitaxel has since been made synthetically by modifying an intermediate substance isolated from yew needles using toxic solvents, or by fermenting cell cultures. Walker's method employs natural enzymes, allowing pharmaceutical companies to reduce the steps involved in making Taxol, while reducing chemical byproducts.

Walker, an assistant professor of chemistry, biochemistry and molecular biology, studies enzymes that assemble the Taxol molecule in Taxus plants. Walker's improvements in the production of Taxol introduced a biological assembly line using enzymes (molecules that facilitate specific chemical reactions) to create the final product. This process is flexible and allows low-cost experimentation, potentially leading to more effective drug variants and better health care treatment.

TechTown: A Collaborative Research Facility at Wayne State University. TechTown, the Wayne State University research and technology park, will soon be home to the first stem cell commercialization lab in Michigan. TechTown's Stem Cell Commercialization Center will be a place where researchers collaboratively accelerate the development of life-saving drugs, and create high-tech companies that bring those treatments to the global marketplace. The lab will serve as a common resource for core biological research using stem cells, which scientists can transfigure into a replica of any cell in the body. Stem cells are the raw material for drugs that can treat everything from juvenile diabetes to traumatic brain injury.

Commercial Success in Medical Imaging. University of Michigan professor of radiology Neal Clinthorne has used technology developed at U-M to build smaller medical imaging equipment that is optimized for specific applications, rather than using

16. Clinical trials cited by the National Cancer Institute, from www.cancer.gov/cancertopics/druginfo/paclitaxel, accessed on 4/29/2009.

more expensive all-purpose machines. Clinthorne's company, Xoran, has several products on the market and has filled a niche market by providing smaller and affordable equipment that physicians can use in their offices.

The Ann Arbor-based company has introduced numerous successful products to date. Xoran's first product, the dental mini-CT scanner, was a commercial success, providing oral surgeons with a device that made them more successful in planning implant surgeries, while costing much less than a full CT scanner used in other medical applications. Another Xoran device, the MiniCAT, is designed for sinus and temporal bone imaging for the offices of ear, nose and throat specialists. The devices allow patients to make one stop for an initial exam, diagnostic scan, and the start of their treatment. Today, Xoran is working on a brain imaging scanner for use in a hospital neurointensive care unit.

Slowing Aging and Curing Disease. Wayne State University professor Stanley R. Terlecky has identified a novel technology that can reduce or even eliminate accumulation of free radicals in cells—molecules long suspected of contributing to the aging process and a contributor to serious health problems. His research, which focuses on cells' roles in metabolism, aging, and disease, has led to the formation of EXT Life Sciences, a WSU spin-off company poised to develop and market an over-the-counter skin care product beginning in 2009.

Terlecky created a novel protein therapy that can be delivered into a human cell to neutralize harmful oxidants. This proprietary technology, CATSKL™, has great potential for treating serious health problems including heart attack and stroke complications, inflammation and related arthritic conditions, and type 2 diabetes. In addition, Terlecky's research may prove helpful in the treatment of idiopathic pulmonary fibrosis, a lung disease that currently kills 40,000 people per year in the United States.

Commercializing Drug Treatment Discoveries. U-M professor of chemistry Gary D. Glick has started Lycera Corporation, a company that develops drugs for treating autoimmune diseases. Lycera Corporation is based on Glick's research on drug candidates that affect the immune system. Such drugs could be used for treating immune-system-related diseases such as rheumatoid arthritis, lupus erythematosis, psoriasis, inflammatory bowel disease and graft versus host disease. Recent venture capital financing will enable Lycera to advance its first drug candidate through final studies and move a second candidate into clinical trials.

Preventing Disease in Children. A URC-led consortium of MSU, University of Michigan, Wayne State University, Children's Hospital of Michigan, Henry Ford Health System, Michigan Department of Community Health, and the health departments of each of the five participating counties has secured $57 million in funding from the National Institutes of Health to expand its role in the largest research project ever to study children's health and the causes of ailments such as autism, cerebral palsy, and asthma.

The National Children's Study, headquartered at Michigan State University, will monitor more than 100,000 children from before birth to age 21. The NIH funding will expand the study, started with $18.5 million for research in Wayne County, to include children in Genesee, Grand Traverse, Lenawee and Macomb counties. The project will follow about 1,000 participants in each of the five counties to study the environmental influences that affect them, including toxins, nutrition, physical living conditions and socioeconomic factors. Children will continually be assessed throughout their development.

Dr. Nigel Paneth, MSU professor of epidemiology, and pediatrics and human development and the project's principal investigator, noted that, "This is the largest human health study ever undertaken. By following children from before birth and studying their environment, we will be able to seek out ways to prevent many of the diseases children now suffer from."

Advancing Sound Monitoring. Professor of engineering Yong Xu of Wayne State University is developing a stethoscope alternative that has the potential to change the paradigm for respiratory sound monitoring. Using new technology, Xu is developing an accelerometer-based micro-sensor that is sensitive and compact enough to be worn comfortably throughout the day, yet capable of picking up the weak vibrations given off by breathing.

Xu is now miniaturizing this sensor using silicon, the same material used to fabricate integrated circuits. Using intelligent textile technology, Xu will fashion these micro sensors on a flexible polymer skin, allowing the device to bend with a patient's movement. This polymer skin can be stitched into fabric or made into a bandage, allowing the sensor to be applied to the patient very conveniently.

This type of continuous respiratory sound monitoring could result in improved monitoring of patients under anesthesia, better asthma management, and improved patient monitoring in intensive care units, nursing facilities, emergency medical services, and sleep studies. The device also has potential to be used as non-invasive vital sign monitoring for pilots and other military personnel, for which there is no current method of continuous respiratory sound tracking.

New Technology That Fights Cancer. Biomedical engineer Charles Cain and his colleagues at the University of Michigan have created a novel ultrasound surgical tool that destroys prostate cancer tumors. The patented device uses tightly focused pulses of ultrasound that work like thousands of micro-scalpels to shred and liquefy tumors without damaging surrounding tissues. With the help of the U-M Tech Transfer office and the Wallace H. Coulter Foundation, Cain's team is launching an Ann Arbor-based startup, HistoSonics, to make the non-invasive surgical tool available to patients.

Cain calls his invention a cavitation-based, image-guided ultrasound surgical tool. The use of high-intensity, focused ultrasound produces micro-bubbles through a process called cavitation. Though thermal-ultrasound researchers have traditionally tried to minimize cavitation, after five years studying the properties and behavior of

cavitation micro-bubbles, Cain and his colleagues learned to control them and, subsequently, use them therapeutically in a technique that Cain calls histotripsy.

To perform the technique, a pulse of ultrasound is first used to create a cloud of tens or hundreds of thousands of microscopic bubbles in the target tissue. The bubble cloud reflects sound waves, forming a bright spot on the ultrasound image. That bright spot tells the surgeon exactly where the ultrasound "micro-scalpels" are focused. Then additional pulses of lower-intensity ultrasound agitate the cells in the target tissue, shaking them violently until they rip apart and liquefy. The surgeon controls the location of the beam's focal point with a joy stick and views the procedure on a computer monitor, in real time. Once the bright spot on the ultrasound image vanishes, the surgeon knows the diseased cells have been destroyed. According to Cain the technology has worked very well and is going to revolutionize the way ultrasound therapy is done.

Breakthroughs in Prostate Cancer Treatment. Wayne State University professor Avraham Raz and his research team have identified a new marker for prostate cancer progression that may lead to more effective treatments.

Prostate cancer, one of the most prevalent non-skin cancers in America, affects one in six men. Raz and his team identified a partially degraded form of galectin-3, an inheritable gene, as a marker for prostate cancer progression. When this gene, which is present in late-stage prostate cancer, is reduced, the development of metastatic prostate cancer is inhibited. This finding suggests that galectin-3 may serve as both a diagnostic marker and therapeutic target for future prostate cancer treatments.

Appendix A: Exhibits

The following exhibits are included in this section:

Appendix Table A-1: AEG Comprehensive Life Sciences Definition

Industry Sector	NAICS Code	Description	Percentage of Code in Life Sciences Industry
Biological			
	3254	*Pharmaceutical and Medicine Manufacturing*	
	325411	Medicinal and Botanical Manufacturing	*100%*
	325412	Pharmaceutical preparation manufacturing	*100%*
	325413	In-vitro diagnostic substance manufacturing	*100%*
	325414	Other biological product manufacturing	*100%*
	3259	*All Other Chemical Product and Preparation Manufacturing*	
	325991	Custom Compounding of Purchased Resins	*100%*
	325992	Photographic film, paper, plate, and chemical manufacturing	*100%*
	325998	All other miscellaneous chemical product and preparation manufacturing	*100%*
	3391	*Medical Equipment and Supplies Manufacturing*	
	339111	Laboratory apparatus and furniture manufacturing	*100%*
	339112	Surgical and medical instrument manufacturing	*100%*
	339113	Surgical appliance and supplies manufacturing	*100%*
	339114	Dental equipment and supplies manufacturing	*100%*
	339115	Ophthalmic goods manufacturing	*100%*
	339116	Dental laboratories	*100%*
	3345	*Navigational, Measuring, Electromedical, and Control Instruments Manufacturing*	
	334510	Electromedical apparatus manufacturing	*100%*
	334516	Analytical laboratory instrument manufacturing	*100%*
	334517	Irradiation apparatus manufacturing	*100%*
	5413	*Testing Laboratories*	
	541380	Testing laboratories	*4%*
	5417	*Scientific Research and Development Services*	
	541710	Physical, engineering, and biological research (includes biotechnology)	*100%*
Agricultural			
	1151	*Support Activities for Crop Production*	
	115112	Soil Preparation, Planting, and Cultivating	*1%*
	1152	*Support Activities for Animal Production*	
	115210	Support Activities for Animal Production	*1%*
	1153	*Support Activities for Forestry*	
	115310	Support Activities for Forestry	*10%*
	3112	*Agricultural Feedstock Manufacturing*	
	311221	Wet corn milling	*45%*
	311222	Soybean processing	*1%*
	311223	Other oilseed processing	*17%*
	3113	*Sugar and Confectionery Product Manufacturing*	
	311313	Beet Sugar Manfacturing	*6%*
	3251	*Basic Chemical Manufacturing*	
	325110	Petrochemical Manufacturing	*100%*
	325120	Industrial Gas Manufacturing	1%
	325132	Synthetic Organic Dye and Pigment Manufacturing	*100%*
	325191	Gum and Wood Chemical Manufacturing	*100%*
	325192	Cyclic Crude and Intermediate Manufacturing	*100%*
	325193	Ethyl Alcohol Manufacturing	*100%*
	325199	All other basic organic chemical manufacturing	*100%*
	3252	*Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing*	
	325221	Cellulosic organic fiber manufacturing	*100%*
	3253	*Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing*	
	325311	Nitrogenous fertilizer manufacturing	*100%*
	325312	Phosphatic fertilizer manufacturing	*100%*
	325314	Fertilizer (mixing only) manufacturing	*100%*
	325320	Pesticide and other agricultural chemical manufacturing	*100%*
	5419	*Other Professional, Scientific and Technical Services*	
	541940	Veterinary Services	24%
Medical			
	6113	*Colleges, Universities, and Professional Schools*	
	611310	Colleges, Universities, and Professional Schools	4%
	6215	*Medical and Diagnostic Laboratories*	
	621511	Medical Laboratories	*100%*
	621512	Diagnostic Imaging Centers	*100%*
	6221	*General Medical and Surgical Hospitals*	
	622110	General Medical and Surgical Hospitals	*3%*
	6222	*Psychiatric and Substance Abuse Hospitals*	
	622210	Psychiatric and Substance Abuse Hospitals	*3%*
	6223	*Specialty (except Psychiatric and Substance Abuse) Hospitals*	
	622310	Specialty (except Psychiatric and Substance Abuse) Hospitals	*100%*

Appendix Table A-2: Employment and Payroll in Michigan's Life Sciences Industry

Cluster	Industry Description	% of Industry Included	Employees 1999	Employees 2006	Annual Payroll (thousands) 1999	Annual Payroll (thousands) 2006
Agriculture						
Agriculture and Forestry Support Activities (NAICS 115)						
115112	Soil Preparation, Planting, and Cultivating	1%	1	1	$30	$31
115210	Support Activities for Animal Production	1%	5	6	$123	$177
115310	Support Activities for Forestry	10%	11	9	$301	$285
Food Manufacturing (NAICS 311)						
311221	Wet corn milling	45%	0	0	$0	$0
311222	Soybean processing	1%	0	0	$0	$0
311223	Other oilseed processing	17%	0	0	$0	$0
311313	Beet Sugar Manufacturing	6%	46	39	$1,616	$1,196
Chemical Manufacturing (NAICS 325)						
325110	Petrochemical Manufacturing	100%	30	0	$1,694	$0
325120	Industrial Gas Manufacturing	1%	2	1	$127	$69
325132	Synthetic Organic Dye and Pigment Manufacturing	100%	576	412	$26,836	$23,595
325191	Gum and Wood Chemical Manufacturing	100%	19	10	$1,153	$720
325192	Cyclic Crude and Intermediate Manufacturing	100%	280	0	$16,988	$0
325193	Ethyl Alcohol Manufacturing	100%	0	40	$0	$2,881
325199	All Other Basic Organic Chemical Manufacturing	100%	3,722	2,856	$173,274	$205,689
325221	Cellulosic organic fiber manufacturing	100%	0	52	$0	$3,814
325311	Nitrogenous fertilizer manufacturing	100%	0	10	$0	$375
325312	Phosphatic fertilizer manufacturing	100%	0	0	$0	$0
325314	Fertilizer (mixing only) manufacturing	100%	300	247	$9,026	$9,447
325320	Pesticide and other agricultural chemical manufacturing	100%	148	115	$4,453	$4,594
Professional, Scientific and Technical Services (NAICS 541)						
541940	Veterinary Services	24%	1,661	2,058	$36,583	$55,572
	Subtotal Agricultural Life Sciences		*6,801*	*5,856*	*$272,203*	*$308,444*
Medical						
Colleges, Universities, and Professional Schools (NAICS 6113)						
611310	Colleges, Universities, and Professional Schools	4%	1,089	1,153	$19,619	$25,145
Medical and Diagnostic Laboratories (NAICS 6215)			0			
621511	Medical Laboratories	100%	2,750	3,245	$99,472	$176,231
621512	Diagnostic Imaging Centers	100%	1,873	3,765	$93,263	$214,033
Hospitals (NAICS 622)			0			
622110	General Medical and Surgical Hospitals	3%	5,448	5,554	$178,998	$239,915
622210	Psychiatric and Substance Abuse Hospitals	3%	238	161	$8,723	$6,846
622310	Specialty (except Psychiatric and Substance Abuse) Hospitals	3%	65	121	$2,147	$4,983
	Subtotal Medical Life Sciences		*11,463*	*14,000*	*$402,222*	*$667,153*
Biological						
Pharmaceutical and Medicine Manufacturing (NAICS 3254)						
325411	Medicinal and Botanical Manufacturing	100%	500	494	$23,401	$32,019
325412	Pharmaceutical preparation manufacturing	100%	7,231	6,358	$316,341	$384,914
325413	In-vitro diagnostic substance manufacturing	100%	407	353	$16,722	$39,010
325414	Other biological product manufacturing	100%	436	547	$21,383	$32,785
Other Chemical Product and Preparation Manufacturing (NAICS 3259)						
325991	Custom Compounding of Purchased Resins	100%	1,110	1,396	$45,653	$71,151
325992	Photographic film, paper, plate, and chemical manufacturing	100%	165	369	$6,283	$20,443
325998	All other miscellaneous chemical product and preparation manufacturing	100%	1,921	1,457	$91,504	$87,750
Navigational, Measuring, Electromedical, and Control Instruments Manufacturing (NAICS 3345)						
334510	Electromedical apparatus manufacturing	100%	300	605	$31,260	$36,303
334516	Analytical laboratory instrument manufacturing	100%	933	1,376	$34,937	$83,883
334517	Irradiation apparatus manufacturing	100%	30	25	$1,550	$1,491
Medical Equipment and Supplies Manufacturing (NAICS 3391)						
339111	Laboratory apparatus and furniture manufacturing	100%	833	993	$27,673	$47,900
339112	Surgical and medical instrument manufacturing	100%	1,397	1,580	$55,481	$63,728
339113	Surgical appliance and supplies manufacturing	100%	2,738	3,169	$126,177	$196,684
339114	Dental equipment and supplies manufacturing	100%	440	413	$15,610	$19,066
339115	Ophthalmic goods manufacturing	100%	221	280	$8,357	$9,526
339116	Dental laboratories	100%	1,687	1,317	$46,940	$48,705
Architectural, Engineering, and Related Services (NAICS 5413)						
541380	Testing laboratories	4%	134	219	$5,443	$14,077
Scientific Research and Development Services (NAICS 5417)						
541710	Physical, engineering, and biological research (includes biotechnology)	100%	32,696	38,255	$3,066,255	$4,436,215
	Subtotal Biological Life Sciences		*53,179*	*59,206*	*$3,940,969*	*$5,625,650*
Statewide Life Science Industry Totals:			**71,443**	**79,062**	**$4,615,394**	**$6,601,247**
	% of Total Michigan Employment/Earnings:		1.8%	*2.1%*	*3.3%*	*4.4%*

Base Data: US Census Bureau County Business Patterns
Analysis: Anderson Economic Group, LLC

Appendix Table A-3: Employment and Payroll in U.S. Life Sciences Industry

Cluster	Industry Description	% of Industry Included	Employees 1999	Employees 2006	Annual Payroll (thousands) 1999	Annual Payroll (thousands) 2006
Agriculture						
Agriculture and Forestry Support Activities (NAICS 115)						
115112	Soil Preparation, Planting, and Cultivating	1%	153	110	$ 4,217	$ 3,765
115210	Support Activities for Animal Production	1%	167	191	$ 3,267	$ 5,060
115310	Support Activities for Forestry	10%	1,415	1,349	$ 31,978	$ 43,882
Food Manufacturing (NAICS 311)						
311221	Wet corn milling	45%	4,325	3,994	$ 196,906	$ 257,304
311222	Soybean processing	1%	65	65	$ 2,449	$ 2,927
311223	Other oilseed processing	17%	374	308	$ 11,314	$ 13,995
311313	Beet Sugar Manufacturing	6%	436	376	$ 15,983	$ 15,591
Chemical Manufacturing (NAICS 325)						
325110	Petrochemical Manufacturing	100%	10,826	8,233	$ 688,004	$ 733,531
325120	Industrial Gas Manufacturing	1%	116	122	$ 5,715	$ 7,303
325132	Synthetic Organic Dye and Pigment Manufacturing	100%	8,272	5,337	$ 374,582	$ 298,362
325191	Gum and Wood Chemical Manufacturing	100%	2,417	2,057	$ 90,350	$ 89,824
325192	Cyclic Crude and Intermediate Manufacturing	100%	7,830	2,919	$ 475,997	$ 227,380
325193	Ethyl Alcohol Manufacturing	100%	1,625	4,262	$ 65,193	$ 253,149
325199	All Other Basic Organic Chemical Manufacturing	100%	83,689	69,713	$ 4,781,041	$ 4,837,982
325221	Cellulosic organic fiber manufacturing	100%	3,381	1,374	$ 139,439	$ 68,839
325311	Nitrogenous fertilizer manufacturing	100%	5,600	3,577	$ 289,298	$ 220,640
325312	Phosphatic fertilizer manufacturing	100%	8,268	6,141	$ 390,373	$ 384,805
325314	Fertilizer (mixing only) manufacturing	100%	9,038	8,851	$ 298,035	$ 344,683
325320	Pesticide and other agricultural chemical manufacturing	100%	14,443	11,179	$ 710,109	$ 560,537
Professional, Scientific and Technical Services (NAICS 541)						
541940	Veterinary Services	24%	49,329	67,599	$ 1,037,026	$ 1,909,616
	Subtotal Agricultural Life Sciences		*211,769*	*197,757*	*$9,611,275*	*$10,279,174*
Medical						
Colleges, Universities, and Professional Schools (NAICS 6113)						
611310	Colleges, Universities, and Professional Schools	4%	52,072	61,369	$ 1,294,171	$ 1,956,697
Medical and Diagnostic Laboratories (NAICS 6215)						
621511	Medical Laboratories	100%	105,229	139,027	$ 3,705,049	$ 6,793,913
621512	Diagnostic Imaging Centers	100%	47,264	89,040	$ 2,277,781	$ 5,156,224
Hospitals (NAICS 622)						
622110	General Medical and Surgical Hospitals	3%	137,989	148,615	$ 4,506,000	$ 6,735,000
622210	Psychiatric and Substance Abuse Hospitals	3%	7,340	6,502	$ 238,699	$ 278,391
622310	Specialty (except Psychiatric and Substance Abuse) Hospitals	3%	4,687	5,999	$ 158,303	$ 277,754
	Subtotal Medical Life Sciences		*354,581*	*450,552*	*$12,180,003*	*$21,197,979*
Biological						
Pharmaceutical and Medicine Manufacturing (NAICS 3254)						
325411	Medicinal and Botanical Manufacturing	100%	28,661	26,354	$ 1,705,978	$ 1,985,465
325412	Pharmaceutical preparation manufacturing	100%	129,022	163,198	$ 7,837,789	$ 12,644,200
325413	In-vitro diagnostic substance manufacturing	100%	39,039	26,971	$ 2,257,934	$ 2,008,275
325414	Other biological product manufacturing	100%	22,082	33,220	$ 1,207,994	$ 2,749,572
Other Chemical Product and Preparation Manufacturing (NAICS 3259)						
325991	Custom Compounding of Purchased Resins	100%	27,297	21,553	$ 1,036,698	$ 1,043,784
325992	Photographic film, paper, plate, and chemical manufacturing	100%	34,129	30,077	$ 1,778,089	$ 1,393,988
325998	All other miscellaneous chemical product and preparation manufacturing	100%	36,751	35,123	$ 1,649,234	$ 1,792,354
Navigational, Measuring, Electromedical, and Control Instruments Manufacturing (NAICS 3345)						
334510	Electromedical apparatus manufacturing	100%	55,695	56,377	$ 2,884,929	$ 4,232,775
334516	Analytical laboratory instrument manufacturing	100%	35,320	31,445	$ 1,900,515	$ 2,195,026
334517	Irradiation apparatus manufacturing	100%	14,460	17,908	$ 779,304	$ 1,540,422
Medical Equipment and Supplies Manufacturing (NAICS 3391)						
339111	Laboratory apparatus and furniture manufacturing	100%	18,557	21,703	$ 806,825	$ 1,107,555
339112	Surgical and medical instrument manufacturing	100%	107,519	100,499	$ 4,500,211	$ 5,960,833
339113	Surgical appliance and supplies manufacturing	100%	88,218	104,873	$ 3,476,251	$ 5,517,138
339114	Dental equipment and supplies manufacturing	100%	18,439	15,550	$ 672,854	$ 725,783
339115	Ophthalmic goods manufacturing	100%	27,158	24,302	$ 955,608	$ 1,117,574
339116	Dental laboratories	100%	42,336	47,088	$ 1,158,812	$ 1,706,513
Architectural, Engineering, and Related Services (NAICS 5413)						
541380	Testing laboratories	4%	3,521	4,006	$ 133,807	$ 201,895
Scientific Research and Development Services (NAICS 5417)						
541710	Physical, engineering, and biological research (includes biotechnology)	100%	457,088	615,400	$ 35,156,762	$ 54,787,161
	Subtotal Biological Life Sciences		*1,185,292*	*1,375,647*	*$69,899,594*	*$102,710,313*
US Life Science Industry Totals:			**1,751,641**	**2,023,956**	**$ 91,690,872**	**$ 134,187,466**
% of Total US Employment/Earnings:			*1.6%*	*1.7%*	*2.6%*	*2.8%*

Base Data: US Census Bureau County Business Patterns
Analysis: Anderson Economic Group, LLC

Appendix Table A-4: NSF Life Science Definition by NCES Classification

Cluster	*NCES Code*	*Description*
Agriculture		
	01.03	Agricultural Production Operations
	01.0303	Aquaculture
	01.07	International Agriculture
	01.12	Soil Sciences
	03	Natural Resources and Conservation
	04.06	Landscape Architecture
Also includes agricultural chemistry, agronomy, animal science, conservation, fish and wildlife, forestry, and horticulture		
Medical		
	26.0209	Radiation Biology/Radiobiology
	26.9999	Biological and Biomedical Sciences, Other
	30.2401	Neuroscience
	51.04	Dentistry (DDS or DMD)
	51.1201	Medicine (MD)
	51.1610	Psychiatric or Mental Health Nurse/Nursing
	51.17	Optometry (OD)
	51.19	Osteopathic Medicine/ Osteopathy (DO)
	51.20	Pharmacy/Pharamceutical Sciences, and Administration
	51.21	Podiatric Medicine/Podiatry (DPM)
	51.22	Public Health
	51.24	Veterainary Medicine (DVM)
Also includes anethesiology, cardiology, colon and rectal surgery, dental/oral surgery, dermatology, family medicine, gastroenterology, general medicine, general surgery, hematology, internal medicine, medical programs, other, neonatal/perinatal medicine, neurological surgery, neurology, nuclear medicine, nuclear radiology, obstetrics and gynecology, oncology, ophthalmology, orthopedics/orthopedic surgery, otorhinolaryngology, pediatrics, pharmacology, physical and rehabilitative medicine, plastic surgery, preventative medicine, psychiatry, thoracic surgery, urology		
Biological		
	19.05	Foods, Nuritrition, and Related Services
	26.01	Biology, General
	26.0202	Biochemistry
	26.0203	Biophysics
	26.03	Botany/Plant Biology
	26.04	Cell/Cellular Biology and Anatomical Sciences
	26.0403	Anatomy
	26.05	Microbiological Sciences and Immunology
	26.0503	Medical Microbiology and Bacteriology
	26.0505	Parasitology
	26.0507	Immunology
	26.0701	Zoology/Animal Biology
	26.0702	Entomology
	26.0707	Animal Physiology
	26.0799	Zoology/Animal Biology, Other
	26.0804	Animal Genetics
	26.09	Physiology, Pathology and Related Sciences
	26.0910	Pathology/Experimental Pathology
	26.1001	Pharmacology
	26.1004	Toxicology
	26.1101	Biometry/Biometrics
	26.1102	Biostatistics
	26.1301	Ecology
	26.1309	Epidemiology
	26.99	Biological and Biomedical Sciences, Other
	30.1901	Nutrition Sciences
Also includes allergies and immunology, biogeography, biotechnology, pathology, physical anthropology, and virology		

Base Data: National Science Foundation, NCES Classification and Illustrative Disciplines

Appendix A-5

At a Glance...The Economic Contributions of Michigan's University Research Corridor

Summary of 2008 Annual Economic Impact Report

ANDERSON ECONOMIC GROUP

- The University Research Corridor (URC) is an alliance of Michigan's three largest academic research institutions: Michigan State University, University of Michigan, and Wayne State University.
- The URC's mission is to accelerate economic development in Michigan by educating students, attracting talented workers to Michigan, supporting innovation, and encouraging the transfer of technology to the marketplace.
- The URC makes significant economic contributions to the state's economy. Findings from AEG's 2008 *Annual Economic Impact Report* (available at: www.AndersonEconomicGroup.com) show:

1. Enormous Economic Benefits of the University Research Corridor

- URC universities collectively spent $6.7 billion on operations in FY 2007. This is about 2% of all economic activity in the state, as measured by Michigan's gross state product.
- 552,320 URC alumni living in Michigan earned $25.2 billion in salary and wages in 2007, or 13.3% of all wage and salary income in Michigan.
- The URC employed 48,760 full-time faculty and staff throughout the state of Michigan in FY 2007.
- In FY 2007, Michigan's residents were over $13.3 billion richer due to the URC.

2. URC Contributes Significantly to R&D, Patents, Licenses, and Start-ups in Michigan

- In 2006, the URC spent $1.47 billion on research and development. This is 94% of all R&D spending by universities (public and private) in Michigan.
- On average, the URC received 126 patents and 122 licenses annually between 2002 and 2007.
- The URC helped cultivate an average of 15 start-up companies annually between 2002 and 2007.

3. URC Brings Millions of Dollars in Federal Investment to Michigan

- The URC brought $855 million in federal research dollars to Michigan in 2006. This is money that paid salaries and bought supplies and equipment, fueling other economic activity in the state.

4. Michigan's URC is Among the Top University Clusters in the U.S.

- The URC spends more on R&D than peer university clusters in Massachusetts (MIT, Harvard, and Tufts) and Illinois (University of Illinois, Univ.ersity of Chicago, and Northwestern).
- The URC received more patent grants on average each year between 2002 and 2007 than the North Carolina, Pennsylvania, and Southern California university clusters.
- Between 2002 and 2007, the URC helped cultivate 8 more start-up companies on average annually than North Carolina's Research Triangle university cluster.
- The URC was the fourth most effective cluster of the seven clusters we analyzed in turning research expenditures into licensing revenue.

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Appendix B:Definition and Estimation Methodology

Our comprehensive definition of the life sciences industry is composed of specific industrial sectors identified by North American Industry Classification System (NAICS) codes, which is how the U.S. Census Bureau reports industry data. Because there is no universally accepted definition of the life sciences, we employed the methodology described in this section to arrive at a comprehensive industry definition.

After establishing the industry definition, we used U.S. County Business Patterns data on employment and payroll in past years (1999 and 2006) to describe the life sciences industry both nationally and in Michigan. For those NAICS codes where employment and payroll information were unavailable, we employed the estimating techniques described in this section to make accurate payroll and employment estimates for Michigan's life science industry.

DEFINING THE LIFE SCIENCES INDUSTRY

To define the life sciences industry we surveyed existing industry definitions, estimated the percentage of industry activity that should be defined as life sciences, and divided the life sciences industry into three clusters.

Surveyed existing definitions. We reviewed definitions of life sciences used in previous AEG reports, by the National Science Foundation, and in a recent (2009) report by the University of Michigan's Institute for Research on Labor, Employment, and the Economy in their study *The Contribution of the Bioscience Industry to the Economy of Michigan*. These definitions vary from focusing solely on traditional life sciences to definitions that incorporate agricultural and health care industry codes.

We began with our previous definition of life sciences from the report *Life Sciences Industry in Michigan: Employment, Economic, and Fiscal Contributions to the State's Economy* by Patrick L. Anderson and Scott D. Watkins (February 2004) that defined life sciences industries as "businesses whose work helps to improve the quality of human life through the research, development, and application of biological processes, tools, and advanced medical treatments." We included the NAICS industries in AEG's 2004 definition and added several industries from the U-M study. We also included portions of health care industries and agricultural industries whose activities fit the definition described above. We worked with Michigan State University to identify the relevant agricultural industries where research and development is being conducted.

Estimated percentage of industries to include in definition. After establishing the set of industries by NAICS codes to include in our comprehensive industry definition, we determined what percentage of each industry represented life science activity. Final percentages of each industry included were determined through an analysis of each NAICS code's product category distributions or, where applicable, according to the data on subsets of activity within the industry, as reported in the U.S. Census Bureau's 2002 Census of Business. We also reviewed occupational

data to determine how much of each industry's payroll was going towards researchers in the industry.

Divided industry into three clusters. Based on the definition of each NAICS industry given by the U.S. Census Bureau, as well as each code's classification elsewhere (namely in the National Science Foundation's classifications) we organized the NAICS codes in our life sciences industry definition into one of the following activity clusters: biological, agricultural, and medical.

The list of all NAICS codes included in our comprehensive life sciences industry definition, as well as the percentage of each that is apportioned to the life sciences industry can be found in Appendix Table A-1, "AEG Comprehensive Life Sciences Definition," on page A-2.

ESTIMATING MISSING EMPLOYMENT AND PAYROLL DATA

For various NAICS industries, predominantly in the agricultural cluster, specific employment and payroll data was not available at the 6-digit level. In order to accurately represent the size and importance of Michigan's life science industry, the employment numbers and payroll levels for NAICS codes without sufficient data were estimated. In total, 22 codes required AEG estimation for one or both of the years reported. We used the following methodology to estimate missing employment and payroll data.

Employment Numbers. The Census Bureau often withholds specific payroll and employment data when releasing it would provide information about individual businesses. In our data set, we found missing employment given as a range. When confronted with this situation, we looked at the total employment in the higher three, four, or five digit NAICS category (depending on the code in question). We used this total number, and any more detailed subcategory data given for the industry, to determine an appropriate estimate for the industry without an exact employment figure. Often we were able to use the employment figures in previous or subsequent years to determine the trend of the NAICS industry in question. This allowed us to make our estimate as precise as possible.

Payroll Data. For missing payroll numbers we used the average wage of the first available higher level of industry data (five, four, and three digit industries) provided. Occasionally when payroll information was given for several years, but not for one year, we used the industry average of the year closest to it in order to estimate total payroll.

DATA ADJUSTMENTS

In addition to our general methodology for estimation described above, we needed to account for changes in NAICS code classifications that occurred between 2002 and 2003. Prior to 2003, county business pattern reports classified "Auxiliaries" under NAICS code 95. Establishments considered to be "Auxiliaries" were those that provided primary support services in 12 different areas, one of which was Scientific Research and Development (NAICS 541710). As a result, 1999 County Business Pattern data for NAICS code 541710 fails to account for Scientific Research and Development employment, payroll, and establishments that were

classified as auxiliaries. This changed in 2003 when auxiliaries were coded based on the primary support function that they provided. The 2003 county business pattern data for NAICS code 541710 includes employees, payroll, and establishments that were classified differently in 1999 county business pattern reports.

Since this NAICS code is part of our biological cluster and we used 1999 as a benchmark year in our study, it was necessary to adjust 1999 data for this code to make it comparable to data from our other benchmark year, 2006. We adjusted the NAICS 541710 data from 1999 by first estimating the annual growth rate for industries in that code between 1998 and 2002 (prior to the inclusion of auxiliaries). For the State of Michigan, the annual growth rate for NAICS 541710 was 10.8% during those years. The annual growth rate in that code for the nation as a whole was 6.6%. With the knowledge that the industries within NAICS 541710 in fact grew between 2001 and 2003, we assumed a conservative annual growth rate of 5% (substantially lower than estimates for industry growth in Michigan or the U.S. as a whole), and, using 2003 data as starting point, adjusted backwards to arrive at estimated employment and payroll levels for NAICS 541710 in 1999.

As NAICS 541710 was the only code included in our life sciences definition which was substantially affected by the reclassification of auxiliaries, the estimation method described here was only applied to NAICS industry 541710.

Appendix C: About Anderson Economic Group

ABOUT ANDERSON ECONOMIC GROUP

Anderson Economic Group, LLC (AEG) was founded in 1996 and today has offices in East Lansing, Michigan and Chicago, Illinois. AEG is a research and consulting firm that specializes in economics, public policy, financial valuation, and market research. AEG's past clients include:

- *Governments* such as the states of Michigan, North Carolina, and Wisconsin; the cities of Detroit, Cincinnati, Norfolk, and Fort Wayne; counties such as Oakland County, Michigan, and Collier County, Florida; and authorities such as the Detroit-Wayne County Port Authority.
- *Corporations* such as GM, Ford, Delphi, Honda, Taubman Centers, The Detroit Lions, PG&E Generating; SBC, Gambrinus, Labatt USA, and InBev USA; Spartan Stores, Nestle, automobile dealers and dealership groups representing Toyota, Honda, Chrysler, Mercedes-Benz, and other brands.
- *Nonprofit organizations* such as Michigan State University, Wayne State University, University of Michigan, Van Andel Institute, the Michigan Manufacturers Association, United Ways of Michigan, Service Employees International Union, Automation Alley, the Michigan Chamber of Commerce, and Detroit Renaissance.

Visit AEG's website at: http://www.AndersonEconomicGroup.com.

ABOUT THE AUTHORS

Caroline M. Sallee. Ms. Sallee is a Consultant and Director of the Chicago office at Anderson Economic Group, working in the Public Policy, Fiscal, and Economic Analysis practice area. Ms. Sallee's background is in applied economics and public finance. Ms. Sallee was a primary author of the first two *Annual Economic Impact Report*s for Michigan's University Research Corridor. Her recent work includes fiscal and economic impact studies for Michigan State University, Wayne State University, and the benchmarking of Michigan's business taxes with other states in a project for the Michigan House of Representatives.

Ms. Sallee holds a Master of Public Policy degree from the Gerald R. Ford School of Public Policy at the University of Michigan and a Bachelor of Arts degree in economics and history from Augustana College. Ms. Sallee has been with Anderson Economic Group since 2005.

Hilary A. Doe. Ms. Doe is a Senior Analyst at Anderson Economic Group working in the Public Policy, Fiscal and Economic Analysis practice area. Ms. Doe's background is in economics, public finance, and political science.

Prior to joining Anderson Economic Group, Ms. Doe held positions with the Brookings Institution and the Detroit Economic Growth Corporation. Additionally, Ms. Doe served as the Midwest Regional Coordinator for a national think tank, the Roosevelt Institution, where she focused on economic and regional development policy.

Ms. Doe holds a Master's degree in Public Policy from the University of Michigan's Gerald R. Ford School of Public Policy, and a Bachelor of Arts degree in Political Science from the University of Michigan.

Patrick L. Anderson. Mr. Anderson, is the principal and CEO of Anderson Economic Group LLC, a consulting firm specializing in economics, market research, public policy, and business valuation. The firm he founded in 1996 now has offices in Michigan and Illinois, and a client list that includes all the major automakers, numerous state and local governments, research universities, economic development and trade associations, franchises in the automobile, retail and beer & wine industries, and law firms across the United States.

Mr. Anderson has taken a leading role in several major public policy initiatives in his home state; he was the author of the 1992 Term Limit Amendment to the Michigan Constitution, and also the author of the 2006 initiated law that repealed the state's 4-decade-old Single Business Tax. Before founding Anderson Economic Group, Mr. Anderson was the deputy budget director for the State of Michigan under Governor John Engler, and Chief of Staff for the Michigan Department of State.

Mr. Anderson has written over 100 published works, including the book *Business Economics and Finance* and the chapter on business valuation in the book *Litigation Economics*. He is also the executive editor of the *State Economic Handbook*, and his 2004 article "Pocketbook Issues and the Presidency" won the award for the best business economics paper from the National Association of Business Economics.