Growing Talent:
Meeting the Evolving Needs of the Massachusetts Life Sciences Industry

Research Findings and Recommendations from the Life Sciences Talent Initiative

Commissioned by:

The Massachusetts Life Sciences Center
The Massachusetts Biotechnology Council

Prepared by:
The University of Massachusetts Donahue Institute

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Growing Talent reports the research, findings and recommendations of the Life Sciences Talent Initiative, a comprehensive one-year study of talent needs in the Massachusetts life sciences industry and the capacity of the state's higher education institutions and workforce training organizations to respond.

LSTI was conducted by the University of Massachusetts Donahue Institute for the Massachusetts Life Sciences Center and the Massachusetts Biotechnology Council. The initiative was guided by a steering committee composed of the research team, project sponsors and other key stakeholders. Additional insight was provided by an Advisory Committee representing leaders in industry, state government and higher education; an Academic Task Force composed of leaders from public and private colleges and universities, and a Workforce Panel representing training organizations, vocational-technical schools and other leaders in the workforce development system. The UMass Donahue Institute and LSTI sponsors acknowledge and thank the project staff and advisors, who are listed in Appendix A of this report.

LSTI Advisory Committee
Zoltan Csimma, Genzyme Corporation, Chair

LSTI Academic Task Force
Dr. George Langford, formerly of theUniversity of Massachusetts Amherst, Chair

LSTI Workforce Panel
Nancy Snyder, Commonwealth Corporation, Chair

UMass Donahue Institute LSTI Project Team
Robin Sherman, LSTI Project and Research Manager
Dr. J. Lynn Griesemer, Executive Director and Associate Vice President
for Economic Development, President's Office
Dr. Michael Goodman, Director, Economic and Public Policy Research
Dr. Eric Heller, Director, Research and Evaluation
Rebecca Loveland, Research Manager
with Lindsay Koshgarian and Jeremy Wolf

The Massachusetts Life Science Center is a quasi-public state agency, created by the Massachusetts General Court in June 2006 to promote the life sciences in the Commonwealth. The Life Sciences Talent Initiative is the first project funded by the Life Sciences Center. www.masslifesciences.com

The Massachusetts Biotechnology Council is a not-for-profit association of more than 550 biotechnology companies, universities, academic institutions and others dedicated to advancing cutting edge research, development, and product commercialization in the life sciences. www.massbio.org

The UMass Donahue Institute is the public service, outreach and economic development unit of the University of Massachusetts President's Office. Established in 1971, the Institute strives to connect the Commonwealth with the resources of the University, bridging theory and innovation with real world public and private sector applications. www.donahue.umassp.edu

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EXECUTIVE SUMMARY

Massachusetts' ability to grow talent has been its greatest strength in developing a life sciences industry that is a global leader. Building upon that strength is essential to ensuring that the Commonwealth maintains its leadership in the life sciences.

Massachusetts is widely recognized as a science and technology leader and as home to the world's best universities, teaching hospitals and research institutions. While these extraordinary institutions have helped to make Massachusetts a global innovation powerhouse in the life sciences, the engine driving the Massachusetts innovation economy is the Commonwealth's world-class workforce. Highly educated and skilled Massachusetts workers have produced a steady stream of biomedical breakthroughs, and have transformed cutting edge research into commercial therapies, diagnostics, devices and products that are improving and saving lives.

Leaders in business, government and academia agree that the state's highly educated and innovative workforce has been vital to the development of Massachusetts leadership in the life sciences industry. It is why companies such as Genzyme, Biogen Idec and Boston Scientific started and have thrived here. And, it's why multi-national firms such as Abbott, AstraZeneca, Bristol-Myers Squibb, and Novartis have moved here.

However, difficulties meeting the growing and changing talent needs of the industry in Massachusetts represent a challenge in maintaining that leadership position in an increasingly competitive global economy. Industry leaders have reported talent shortages in key functional areas.

That is why, in 2007, the Massachusetts Life Sciences Center and the Massachusetts Biotechnology Council engaged the UMass Donahue Institute to identify current and emerging workforce trends in the state's life sciences super cluster and assess the capacity of the state's public and private higher education institutions to meet the industry's demand for talent. This study will inform the development of a comprehensive strategy to ensure that life sciences employers have the talent they need to succeed and grow in Massachusetts and that our students and workers have the education and training necessary to excel in high-quality, competitive careers.

Growing Talent is the result of a year of intensive research and extensive engagement of leaders in the Commonwealth's biopharmaceutical and medical device firms, research institutions, academic medical centers, public and private higher education institutions, workforce training organizations and state government officials about meeting the need for human capital in the Massachusetts life sciences industry. This effort has been informed by examination of industry trends, analysis of labor market data, a survey of life sciences employers, study of literature on life sciences education, research on higher education and workforce training programs in the Commonwealth, and review of talent strategies in selected states. The Life Sciences Talent Summit, held at UMass Boston, attracted nearly 300 leaders from industry, government, higher education and training organizations. The interest, commitment, and concern of these leaders about the talent needs in Massachusetts are captured in this report.

The good news is that Massachusetts life sciences employers are optimistic about the future of their companies in the state. More than 85 percent stated that they expected to expand within the next two years. Industry executives report that their Massachusetts workforce is highly productive, and the strong economic performance of the sector supports their perspective. Labor market analysis suggests continued expansion of employment in the cluster, which is growing faster than the Massachusetts economy as a whole.

However, sustained growth in the life sciences in Massachusetts is not a foregone conclusion. Research conducted by the UMass Donahue Institute indicates that the Commonwealth's talent advantage in the industry could erode unless state government, employers and educators work together to maintain it.

One early warning sign is a shortage of workers in essential functional areas. Ninety percent of employers surveyed for this project reported difficulty hiring clinical research staff. More than 75 percent of respondents also said they had difficulty finding engineers and employees with regulatory and marketing experience. The concentration and expansion of biopharmaceutical firms, medical device companies and medical research institutions in the Commonwealth have produced a highly competitive marketplace for talent, with salaries higher than industry averages across the full range of available jobs and skill levels.

Life sciences research, development, manufacturing and sales are global industries, and business leaders are keenly aware of the relative advantages of Massachusetts in the international marketplace. So far, the brainpower available in the Commonwealth has outweighed lower costs of doing business elsewhere. Other states and nations, however, are increasing investments in research and education, making themselves very attractive in the global competition for talent. North Carolina has made talent development a strategic priority to support the growth of its life sciences industry cluster. Ireland has developed a national education and training strategy to produce workers for the biomanufacturing facilities that global companies have built there. Singapore is investing billions of dollars in state-of-the art biomedical science research and teaching facilities, and is aggressively recruiting the world's leading scientists.

While the UMass Donahue Institute did not study issues related to science, technology, engineering and math education at the primary and secondary school levels, Massachusetts industry executives interviewed for this study expressed concern about the pipeline of domestic K-12 students motivated and prepared to enter higher education and careers in science. China and India are producing legions of ambitious young scientists and engineers every year, fueling growth of new life sciences companies and expansion of international firms in Asia.

While industry leaders are highly satisfied with the qualifications of scientists graduating from Harvard, MIT, UMass, WPI, Northeastern, Tufts, BU and other leading higher education institutions, they also emphasize that the Commonwealth needs more formal strategies to develop a deep and wide spectrum of life sciences talent. Without a concerted, coordinated effort to produce the next generation of scientists, engineers, medical professionals, entrepreneurs and supporting workers, Massachusetts will fall behind its global competitors in attracting and growing companies in the biomedical sciences.

Over the past year, the Life Sciences Talent Initiative has engaged key stakeholders in a study to guide the development of a life sciences talent strategy. This collaborative effort has resulted in a new understanding of industry needs and the emergence of initiatives to meet them. This report, developed by the UMass Donahue Institute for the Massachusetts Life Sciences Center and the Massachusetts Biotechnology Council, presents findings from the research.

Findings

1. The life sciences industry is a critically important, fast-growing cluster that provides high-quality jobs for Massachusetts residents and generates economic activity across the state economy

The life sciences super cluster employs a broad range of professional, scientific, technical, managerial and other highly educated and skilled workers across several industry sectors, including biotechnology, clinical research, medical devices, pharmaceuticals and related functions. The life sciences labor force encompasses approximately

100,000 workers, not including employment created in additional occupations in other sectors outside the cluster. Life sciences workers are well-compensated, earning 64 percent more than the average Massachusetts salary.[1]

In addition to creating jobs, the life sciences super cluster represents the state's leading export industry, and the cluster brings tens of billions of dollars to Massachusetts in commercial sales and public research funds.

Production of goods and services by life sciences companies contributes to the broader Massachusetts economy through spending by life sciences businesses, institutions and their employees. Every dollar of production in the industry in Massachusetts results in additional production in other industries in the state, and every worker employed by a biotechnology firm, medical device company or academic medical center results in additional jobs in companies outside of the life sciences sectors. These multiplier effects are substantial. For example, studies suggest that each job in the Massachusetts biopharmaceutical industry is linked to the creation of more than three additional jobs in the state economy.[2]

2. Demand for highly qualified talent is growing, both in traditional R&D and expanding downstream business sectors, such as clinical trails and biomanufacturing

The life sciences industry — incorporating bio-pharmaceuticals, medical devices, therapeutics, diagnostics, and the research and development functions of universities and teaching hospitals — is growing nearly 45 percent more rapidly than other industry sectors in the state and will continue to create high-quality employment in the Commonwealth. Occupational analysis using a business-as-usual scenario projects approximately 11,000 net new life sciences jobs in the Commonwealth between 2006 and 2014. This does not include jobs created due to the "multiplier effect," or the impact of additional public and private investment, such as the $1 billion Life Sciences Initiative and the recent moves and expansion by firms such as Novartis, Bristol-Myers Squibb and Organogenesis. Clearly, the state has the potential for greater than business-as-usual growth, but meeting the demand for talent will be critical to realizing that potential.

The majority of new life sciences jobs — more than 80 percent — will require at least a four-year degree. A steady stream of high-level talent is needed in the biological sciences to sustain the state's worldwide leadership position in biomedical research. While most life sciences jobs require higher education, the industry continues to offer opportunities for skilled technicians and manufacturing workers without a four-year degree, especially in the medical device sector.

The state's life sciences workforce is highly mobile, with strong competition among firms inside and outside of the state to hire professional staff in key fields. Industry surveys, focus groups, interviews and industry job posting data suggest that as Massachusetts companies evolve from their focus on early stage research and development to downstream functions such as clinical trials, manufacturing and commercialization, they are seeking expertise in a broad range of functional areas, including clinical research, quality assurance and quality control, legal and regulatory affairs and sales and marketing, as well as in several fields of expertise, such as information technology, chemistry, engineering, toxicology and pharmacology. Life sciences firms rely heavily on an immigrant workforce in R&D and manufacturing, which adds uncertainty for employers due to limitations and restrictions on immigration entry documents including H (1) (b) visas.

[1] PricewaterhouseCoopers, 2007. Data from Bureau of Labor Statistics Quarterly Census of Employment and Wages, and PricewaterhouseCoopers analysis.

[2] Milken Institute. Biopharmaceutical Industry Contributions to State and U.S. Economics, October 2004; and Sum, Andrew et al. The Economic, Labor Market, and Fiscal Performance and Impacts of the Biopharmaceutical Industries of Massachusetts (Research Summary), PhRMA Research Paper No. 15. Center for Labor Market Studies, Northeastern University, August 2007.

3. Massachusetts has many excellent higher education and workforce training programs in life sciences fields, but they need to be better coordinated and more responsive to the needs of industry

Public and private higher education institutions in the Commonwealth offer a broad and comprehensive range of highly regarded programs in the life sciences. But findings from interviews, focus groups, surveys and working groups of employers indicate that the independent efforts of individual institutions and partnerships between companies and campuses are not sufficient to meet the collective needs of the industry as its grows and evolves.

Limited coordination between and among institutions offering life sciences education programs, and lack of effective communication between employers and educators on program offerings and curricula, results in duplication of effort in some areas — such as two-year biotechnology technician programs — while other needs, such as the demand for clinical research associates and skilled machinists — go unmet. Employers and educators are eager to work together to improve student preparation for life sciences careers, but there are few existing mechanisms to facilitate such collaboration.

The overall percentage of Massachusetts higher education graduates with degrees in life sciences fields is comparable to competitor states. Educational statistics and conversations with employers indicate that Massachusetts is strongest in its graduate programs, both in terms of quality of education and share of graduates. Employers report that Massachusetts graduates with bachelor's degrees could be better prepared to enter life sciences careers. They suggest that more laboratory research and industry-related experiences through cooperative education programs and long-term internships would improve undergraduate-level programs in the life sciences.

There are good examples of vocational education, workforce training and two-year degree programs in Massachusetts that are successfully training workers for jobs in biopharmaceutical and medical device companies and research hospitals. The industry trend in Massachusetts, however, is clearly toward hiring at higher levels of education, especially in the biopharmaceutical sector. A bachelor's degree is increasingly required as a minimum qualification for technician and manufacturing positions in biopharmaceutical companies in Massachusetts, whereas similar positions might be filled by workers with short-term training or a two-year degree in other states.

It is important to remember that Massachusetts workers generally have more higher education than their counterparts in other states. While it is possible that the research-intensive nature of the life sciences manufacturing and technical jobs in Massachusetts simply requires workers with advanced education, several industry experts who participated in the Life Sciences Talent Initiative believe that education and training programs below the bachelor's degree could be modified to expand employment opportunities in life sciences sectors and meet industry needs. More work is needed to identify the specific knowledge, attributes and skills required for entry-level life science positions in Massachusetts, and to develop and improve programs designed to prepare students for these opportunities.

Recent work in other states could help guide further research in this area. The San Diego Workforce Partnership has identified nearly 200 life sciences occupations, developed career ladders and described educational requirements for jobs in administration; business development, marketing and sales; clinical research; information systems; process development, manufacturing and production; quality assurance; quality control; regulatory affairs; and research and development.[3] In North Carolina, an "industrial curriculum committee" representing employers and higher education institutions prepared detailed descriptions of the academic, technical, practical, industry-specific and interpersonal knowledge, skills, attributes and experience required for key positions in the

[3] San Diego Workforce Partnership. Biotechnology in the United States: The Industry, Centers, Occupations, and Education Sources. 2006. See also www.biotechwork.org.

biopharmaceutical industry. This information is being used to provide guidance on curriculum development at community colleges and workforce training centers.[4]

4. *Massachusetts needs to increase the pipeline of residents entering both higher education degree programs and careers in the life sciences*

Employers express deep concern about the long-term pipeline of Massachusetts students who are motivated and prepared to succeed in careers requiring academic training in science, technology, engineering and math (STEM). Higher education leaders observe that many students who enter college intending to study science are disadvantaged by inadequate preparation at the high school level, especially in quantitative skills and reasoning. Providing remedial education at the undergraduate level is time consuming and costly for both students and academic institutions.

New Strategies: Growing Talent through Collaboration

Massachusetts has a strong foundation for producing talent to support the life sciences industry. However, the state faces challenges due to current industry dynamics — business creation and expansion; the growing importance of downstream functions; reliance on an immigrant workforce; and the lack of sufficiently strong and widespread connections between and among industry, educational institutions and workforce development organizations.

If industry's future talent needs are to be met, the state, industry, academic institutions and workforce training organizations need to move in new, more effective, and more collaborative ways than we've seen to date.

Action is needed in five priority areas:

Produce and retain more graduate students with interdisciplinary training

Although Massachusetts already has world-class graduate programs, it needs to produce and retain more young scientists who have training in business, management, information technology and regulatory affairs. The state also needs to do a better job of encouraging domestic students to pursue graduate degrees in fields of study that are important to long-term growth of the industry, such as medical science, engineering, computer science and mathematics.

More institutions should consider Professional Science Master's (PSM) degree programs that integrate graduate study in life sciences with professional training in business and management, as Northeastern University, for example, has done. New degrees or certificate programs may be needed in targeted areas such as legal and regulatory affairs, quality control and assurance, and clinical research. Finally, new financial incentives should be considered to help graduate students with the cost of higher education and keep Massachusetts residents with advanced degrees in life sciences fields in the state after they graduate.

Strengthen the interdisciplinary curriculum and experiential learning programs in undergraduate education

Undergraduate curriculum can be enhanced by integrating education in biological sciences with the study of chemistry, physics, mathematics and information science. Harvard and UMass Amherst represent models of this

[4] The North Carolina Biomanufacturing and Pharmaceutical Training Consortium. The Model Employee: Preparation for Careers in the Biopharmaceutical Industry. North Carolina Biotechnology Center, May 2005.

new type of curriculum. On campus, undergraduate life sciences programs should emphasize laboratory skills, research and problem-solving experiences.

Medical device employer representatives singled out WPI's "Major Qualifying Project" requirement as an excellent example of training in applied problem solving. Off-campus work experience in research, development and manufacturing facilities is an important component of preparation for careers in the industry. Industry competition to hire students through Northeastern University's cooperative education program is strong, and life sciences employers are eager to work with other higher education institutions to expand internship and cooperative education opportunities for undergraduates.

Massachusetts also needs to increase the number of domestic students who complete undergraduate courses of study in the science, technology, engineering and math fields that feed the pipeline of entry-level professional workers in the industry. Retention and graduation rates for life sciences majors — especially women, African-American, Latino and first-generation college students — can be improved through stronger advising, tutoring and mentoring efforts. Finally, increased need-based financial assistance is required to ensure that all students have access to higher education in the life sciences.

Improve and target technical training

Special attention needs to be given to exploring the potential for developing life sciences career opportunities for workers with less than a bachelor's degree. More can be done to develop technical education and training programs that prepare young workers for skilled labor positions and help incumbent workers meet the changing needs of their employers. Employers and vocational schools can develop partnerships to train students for well-paying careers in fields with existing and future projected employment demand, such as machinists in the medical device sector.

Workers from other sectors of the economy who have skills relevant to employment in the life sciences, such as chemical and food processing industry workers, can be retrained to take advantage of opportunities in biomanufacturing (e.g., as has recently been done with Polaroid workers at WPI).

Finally, employers can identify occupations where there is an insufficient supply of workers with bachelor's degrees or a high turnover of these workers and partner with community colleges to develop targeted two-year training programs for these positions (e.g., Bristol-Myers Squibb and Mt. Wachusett Community College; and Middlesex Community College with Wyeth in bio-manufacturing).

Further develop and expand the K-12 STEM pipeline

While the scope of research for this report did not include issues at the elementary and secondary education levels, the educators and employers involved in the project consistently and insistently stressed improving preparation and motivation of K-12 students in STEM fields as a top priority. They emphasized that more public outreach is needed to promote the variety of exciting, challenging, rewarding and financially attractive careers available in the Massachusetts life sciences industry, and that K-12 outreach and education programs should be specifically designed to increase the number of female, African-American and Latino students entering higher education in STEM fields. Efforts to address K-12 STEM pipeline issues in Massachusetts could benefit from increased participation by life sciences employers.

Improve communication and coordination between industry and higher education

The Commonwealth needs to strive for the same excellence in producing scientific and professional talent across the education and training system as it has achieved within individual colleges and universities. More communication, coordination and cooperation is needed between schools and educators at all levels — K-12, community colleges, public and private four-year colleges and universities — as well as between educational

institutions and employers to ensure that more Massachusetts students are well-prepared to take advantage of opportunities in one of the state's most dynamic industries, and that life sciences employers continue to be able to find the talent they need here. New approaches must be built on the knowledge and expertise of both educators and employers and will require increased resources from both the public and private sectors.

The Governor's Readiness Project can guide efforts to develop closer relationships between educational institutions and employers. Key proposals of the Readiness Project include: better integration of primary, secondary, and higher education curricula; improvement in public higher education coordination; creation of a Business/Education Taskforce to develop consensus on the education/training needed for college and the 21st century workplace; and expanding partnerships with industry to provide internships and other school-to-career opportunities for students.

The Massachusetts Biotechnology Education Foundation, which has been very successful in developing partnerships between K-12 schools and biotechnology companies, is well-positioned to expand its efforts at the college level, and is prepared to work in cooperation with the Massachusetts Biotechnology Council and the Massachusetts Medical Device Industry Council to expand internship opportunities for college students in life sciences firms.

The Readiness Project also recommends collaboration between educational institutions and employers at a regional level. A potential model is the Worcester Pipeline Collaborative, a comprehensive effort to "encourage, educate and challenge minority and/or economically disadvantaged students for success in the health care and science professions, where they are traditionally underrepresented."

Growing Talent: Early momentum and next steps for government, industry and academia

Over the past year, the Life Sciences Talent Initiative has encouraged a new focus on growing the next generation of scientists, engineers, professionals and workers to sustain the Commonwealth's leadership position in the life sciences. In February 2008, nearly 300 high-level stakeholders from business, higher education and state government participated in the first-ever Life Sciences Talent Summit to help develop the ideas outlined in this report. Since that gathering, key players in industry, state government and educational institutions have begun to develop concrete new initiatives and position themselves to follow through on the findings and recommendations of Growing Talent and the momentum it has generated.

Government leadership through the Life Sciences Center

The Massachusetts Life Sciences Initiative, recently enacted by the Massachusetts legislature and signed by Governor Patrick, presents an opportunity to capitalize on this momentum and move toward a real and sustainable life sciences talent strategy. Under the new legislation, the Massachusetts Life Sciences Center is well-positioned with the resources and authority to take the lead in developing a statewide strategy and providing incentives for educators and employers to work together in educating and training the next generation of life sciences innovators and workers (e.g., new curriculum, new degree programs, expanded co-ops). With its leadership drawn from the highest levels of state government, industry, higher education and research institutions, and its working relationship with the Life Sciences Collaborative, the Center is poised to ensure that both the public and private sectors do their part.

Industry action through the industry associations

Hearing the call to action, leading industry groups — the Massachusetts BioEd Foundation, Massachusetts Biotechnology Council and MassMEDIC — are designing an initiative to guarantee that educators and trainers will always have access to information and prudent guidance regarding the needs of the state's life sciences employers. These organizations are committed to marshalling the insight of employers through the new Massachusetts BioMedical Education and Workforce Development Consortium. This organization will engage academia, workforce developers, state government and other industry partners in determining short- and long-term talent needs, informing curriculum development, and identifying opportunities for concerted public-private-academic action to promote studies and careers in the life sciences in Massachusetts.

Public and private higher education initiatives

Public and private institutions are already acting on opportunities identified in *Growing Talent*. Boston University, Harvard, MIT, Northeastern, Tufts and WPI continue to strengthen their outstanding program offerings in the life sciences. Wentworth Institute recently launched a new bachelor's degree in biomedical engineering. UMass has convened a system-wide task force, undertaken a systematic review of its role in growing life sciences talent, and committed to a strategy for following through on the recommendations of the Life Sciences Talent Initiative across all five campuses. The recent adoption of a new master's degree in clinical sciences at UMass Medical School is an early example of this commitment. These are just a few of the many efforts being developed by educational institutions that directly address the talent needs of the life sciences industry as identified in this report.

Conclusion

The Commonwealth faces significant challenges to growing the talent needed to keep its life sciences industry thriving. With consensus among government, industry and academia on new directions and a strong commitment to collaborate, there is every reason to be confident that Massachusetts can and will meet this challenge.

INTRODUCTION

Industry Overview

Massachusetts is a recognized leader in the global life sciences industry

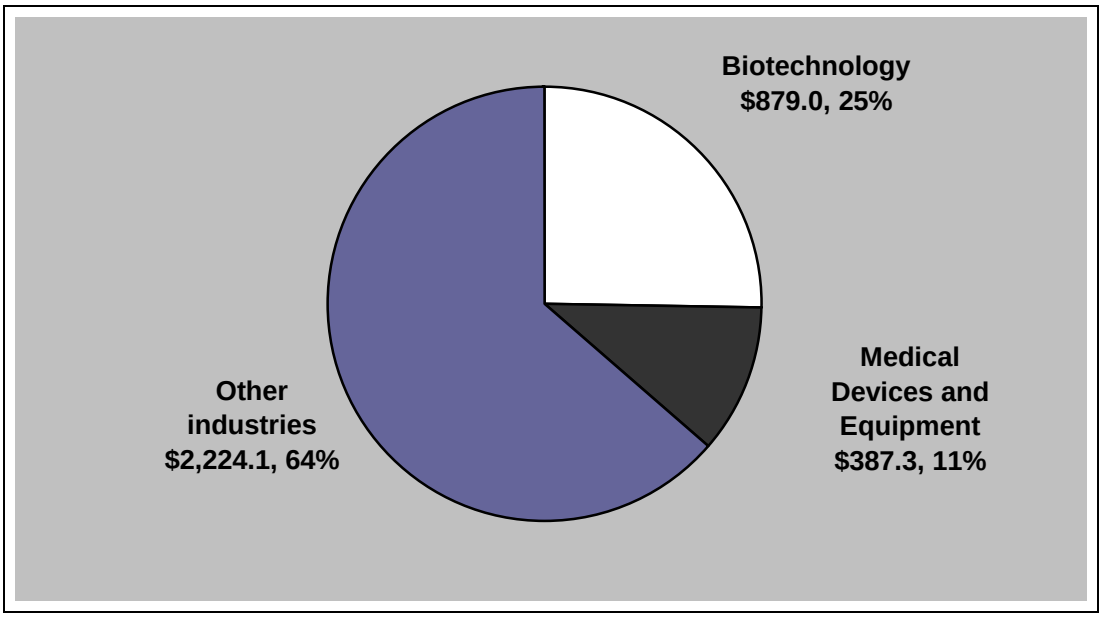
The combination of world-class higher education and research institutions, academic hospitals and a culture of innovation in the Commonwealth have led to ground-breaking scientific advances in the understanding of human health and the treatment of disease. The availability of specialized financial and legal services in the region has facilitated the translation of that knowledge to successful commercial products that improve and extend lives around the world. In 2007, 235 Massachusetts companies were investigating 1,784 new drugs, representing 7.41 percent of the global pharmaceutical development pipeline.[5] Massachusetts ranks second only to California in the award of patents for biopharmaceutical-related products.[6]

The life sciences cluster is one of the cornerstones of the Commonwealth's innovation economy and leads other industries in attracting research funding

Massachusetts institutions receive approximately $2 billion in funding from the National Institutes of Health annually, exceeding all other states in NIH funds per capita. Only California receives more NIH grants overall.[7] In 2007, private venture capitalists invested $1.266 billion in biopharmaceutical and medical device companies in the Commonwealth, representing 36 percent of total private venture capital for all industries in Massachusetts.[8]

[5] Massachusetts Biotechnology Council, personal communication.
[6] Sum, Andrew et al., 2007. Data for 2001 -2005, from U.S. Patent and Trademark Office. The definition of "biopharmaceutical-related products" is broad and includes surgical equipment, instruments and products such as prostheses that might be classified as medical devices.
[7] PricewaterhouseCoopers, 2007. Data from the National Institutes of Health.
[8] Massachusetts Biotechnology Council, personal communication; data from PricewaterhouseCoopers Money Tree Report.

Figure 1: Venture capital invested in Massachusetts industries, 2007 (in millions)



Source: Massachusetts Biotechnology Council; data from PricewaterhouseCoopers Money Tree Report

Massachusetts biopharmaceutical, medical device and related companies generate enormous value through production and exports

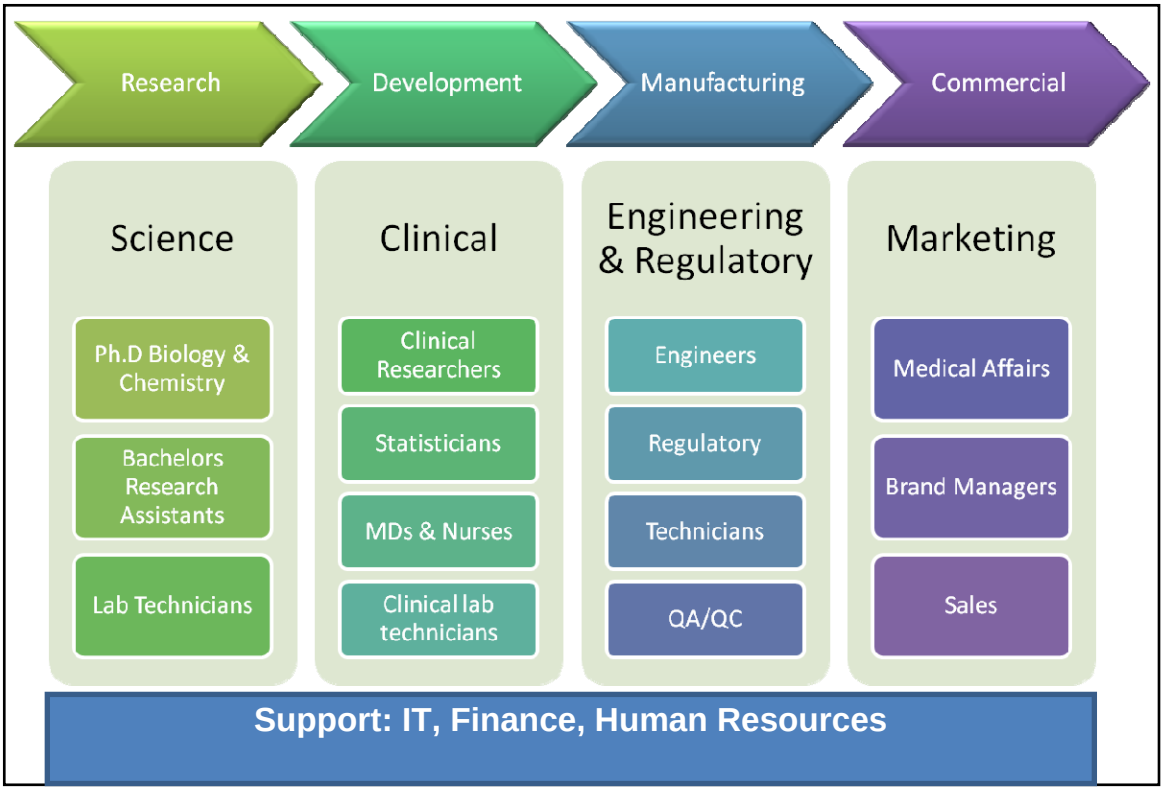
Publicly-traded companies in the life sciences cluster generated $29.824 billion in corporate sales in 2006, an increase of nearly 50 percent in four years, outperforming all other goods-producing sectors of the state economy in total sales and growth over the period.[9] Medical and surgical instruments represent the state's leading export, accounting for $2 billion in 2006.[10] Massachusetts life science exports were valued at $7.5 billion in 2006, accounting for more than 30 percent of total state exports.[11]

The life sciences cluster is an important source of employment for Massachusetts residents

There are nearly 100,000 workers in the life sciences labor force in Massachusetts.[12] These workers are employed in a variety of settings—including but not limited to biotechnology, pharmaceutical and medical device firms, academic medical centers, academic research institutions and independent clinical research organizations—as well as in a broad range of functional areas and occupations.

[9] John Adams Innovation Institute, 2008. Data derived from Standard & Poors COMPUSTAT.
[10] Massachusetts Biotechnology Council, personal communication; data from Massachusetts Export Center.
[11] Worldwide Institute for Strategic Economic Research.
[12] Occupational estimate from UMass Donahue Institute. Estimates from other sources range from 74,000 to 100,000 due to different methodology and different definitions of the industry.

Figure 2: Functions and occupations in the biopharmaceutical product innovation chain



Source: Mark Trusheim, Co-Bio Consulting

Life sciences workers are highly educated and trained. A recent study found that more than 64 percent of workers in Massachusetts biopharmaceutical-related industries had a bachelor's degree, compared to 40 percent of workers in all industries in the state in 2005.[13] The proportion of these highly-educated life sciences workers is expected to increase in the future.

Figure 3: Employed Massachusetts workers by education level, 2003-2005

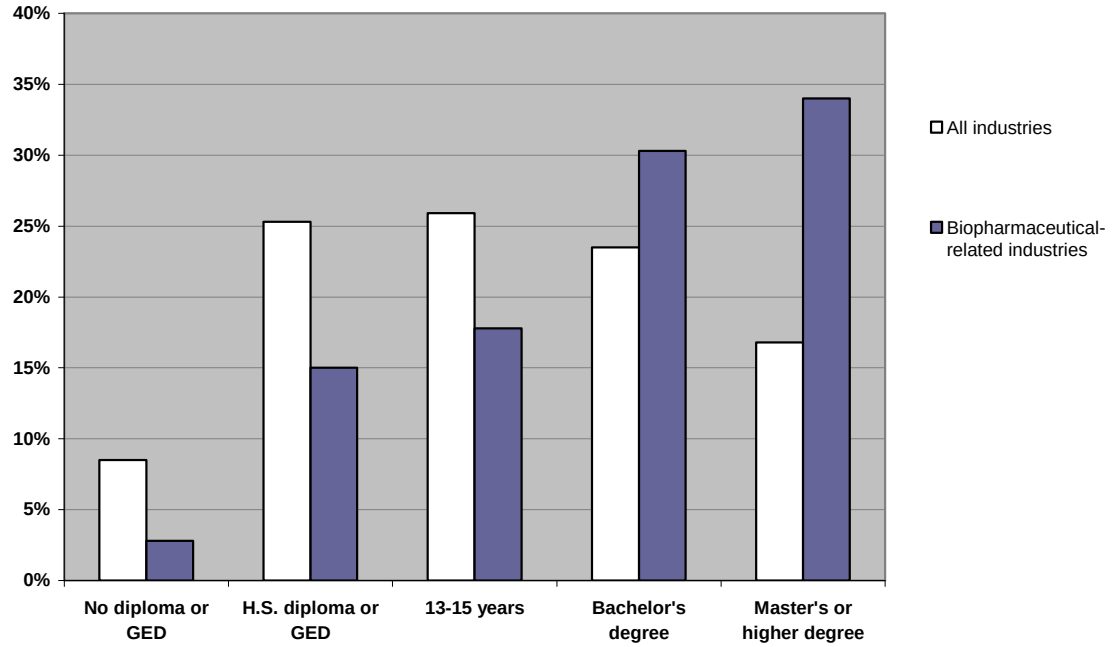
Source: Sum et al., 2007.

High levels of education and productivity in the industry translate into high salaries

Massachusetts life sciences workers earn more than workers in other industries, and more than their peers in most other states.[14] In 2004, the average wage for biopharmaceutical industry workers in Massachusetts was the highest in the nation.[15] Massachusetts biopharmaceutical industry workers earned a wage premium of 23 percent in 2004-2005, compared to workers in other industries in the state.[16]

[13] Sum et al., 2007.
[14] Clayton-Matthews and Loveland, 2004; Sum et al., 2007; PricewaterhouseCoopers, 2007, data from the National Institutes of Health.
[15] Nakajima and Loveland, 2007.
[16] Sum et al, 2007.

Figure 4: Average life sciences wages by sector, 2005



Source: PricewaterhouseCoopers, 2007, data from Bureau of Labor Statistics Quarterly Census of Employment and Wages, and PricewaterhouseCoopers analysis.

Life sciences workers contribute to demographic and fiscal stability in the Commonwealth

The Massachusetts life sciences labor force is predominantly composed of workers in their prime working years and the industry provides an important source of jobs for young, college-educated residents that the state has been losing in recent years.[17] High levels of education and compensation among life sciences workers translate into higher levels of employment and homeownership, supporting state and local budgets though payroll and property taxes. According to a Northeastern University analysis of census data, researchers found that biopharmaceutical-related industry workers are 7 percent more likely to own a home than workers in other industries. As a result, researchers estimate that the average annual value of property taxes paid by employed homeowners working in the biopharmaceutical industry workers was approximately 30 percent higher than for employed homeowners in all industries in Massachusetts in 2005.[18]

Multiplier effects increase the economic value of the Massachusetts life sciences industry

Production of goods and services in the life sciences industry contributes to the broader Massachusetts economy through spending by life sciences businesses, institutions and their employees. There are "multiplier effects" associated with output, earnings, and employment that vary between industries. On a statewide level, output multipliers refer to the change in overall state output as a result of change in output in a particular industry. Earnings multipliers measure change in earnings for all workers as a result of increase or decrease in earnings for workers in the selected industry, and employment multipliers measure changes in all employment resulting from change in employment in a particular industry. Generally, multiplier effects are magnified for industries engaged

[17] Northeastern University Center for Labor Market Studies and UMass Donahue Institute, data from US Census.
[18] Sum et al., 2007.

in manufacturing products for export, and for industries that pay high salaries, both of which apply to the Massachusetts life sciences industry.

A 2004 University of Massachusetts study of the impact of the Massachusetts medical device industry on the state economy estimated that a $100 increase medical-device output is associated with an additional $45 of output from all Massachusetts firms, while every 100 jobs in medical device firms is associated with another 79 jobs statewide.[19] Northeastern University recently conducted a series of studies of the economic impact of biopharmaceutical-related industries on Massachusetts; estimated multiplier effects are displayed in Table 1.

Table 1: Estimated multiplier effects for biopharmaceutical-related industries in Massachusetts, 2007

Type of multiplier	Pharmaceutical and Medicine Manufacturing	Surgical and Medical Instrument Manufacturing	Surgical Appliances and Supplies Manufacturing	Scientific Research and Development Services
Output	2.066	2.051	2.014	2.14
Earnings	3.281	2.299	2.386	1.715
Employment	6.033	3.5	2.979	2.414

Source: Sum et al., 2007

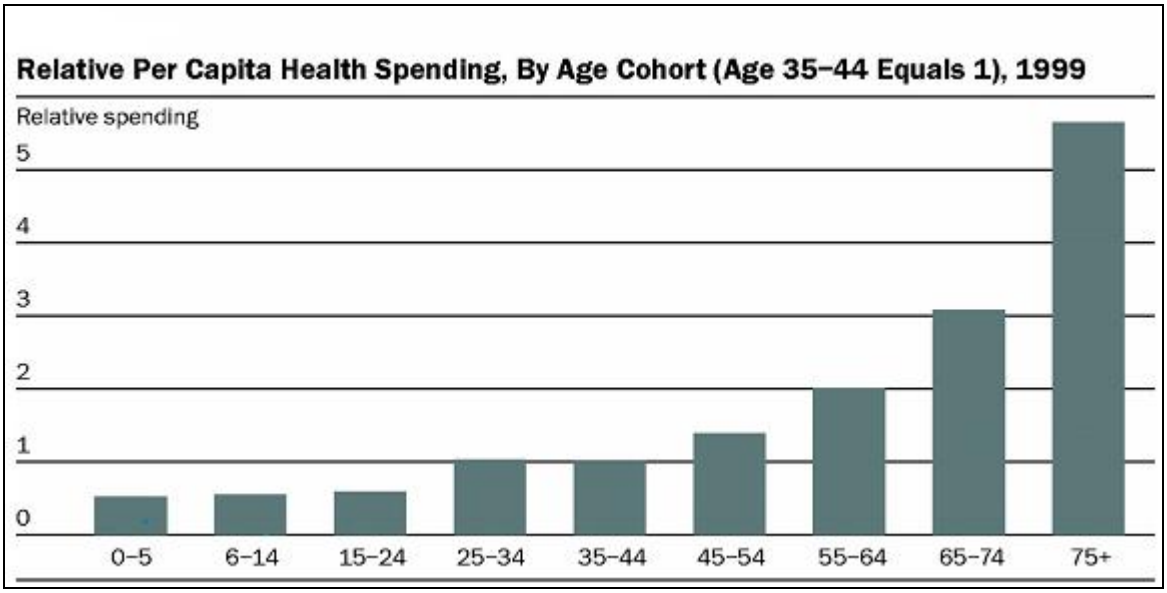
Global trends provide an opportunity for the Commonwealth to continue its leadership in the life sciences industry

Scientific trends in the global health sciences field provide a basis for Massachusetts researchers and biopharmaceutical and medical device firms to continue their leading role in the industry. Scientists affiliated with the state's leading academic institutions are well-positioned to take advantage of the convergence of scientific disciplines—biology, chemistry, physics, engineering, mathematics and computer and information technology—in the understanding and treatment of disease.[20] One example of this convergence is the development of personalized medicine, which designs treatments for disease based on understanding the specific genetic profile of the patient, instead of merely addressing the symptoms of that disease. Academic researchers at Harvard, MIT and UMass Medical School are global leaders in basic research on genome-based medicine, and scientists working at Massachusetts companies such as Genzyme have demonstrated early and sustained success in applying this knowledge.[21]

Economic and demographic trends also provide grounds for optimism. North America and Europe currently represent the largest markets for products produced by Massachusetts life sciences companies, and both regions are characterized by aging populations. Spending on health care is strongly correlated with aging, as shown in Figure 5.

[19] Clayton-Matthews and Loveland, 2004.
[20] MassInsight Corporation, 2008.
[21] MassInsight Corporation, 2008.

Figure 5: Health care spending by age cohort, 1999



Source: "Trends in Medical Spending by Age, 1963-1999," E. Meara, C. While and D.M. Cutler, unpublished paper, Harvard University, 27 March 2003; originally published in "Does the Aging of the Population Really Drive the Demand for Health Care?" Uwe Reinhardt, *Health Affairs*, Volume 22, Number 6.

Increasing prosperity in China, India and other developing nations can also be expected to boost demand for the type of cutting-edge life science products and technology produced in Massachusetts.

Global and national trends also indicate threats to the industry in Massachusetts

Other states and nations around the world recognize the growth potential of the life sciences industry and its ability to generate jobs and economic activity. Global competition to attract research and manufacturing facilities is intensifying, and pressure to reduce the cost of health care is making the price of producing drugs and devices an increasingly important factor in this competition.[22]

The Commonwealth's competitors recognize the importance of talent to the life sciences industry, and are making significant investments in primary, secondary and higher education systems and institutions and scientific research facilities to attract, retain and develop leading scientists. Recent studies have found that Massachusetts is falling behind in producing high school graduates who are motivated and prepared to continue studies in science, technology, engineering and math fields.[23] China and India are producing increasing numbers of highly-educated life scientists and engineers, and the combination of increasing immigration restrictions in the United States and growing opportunities in the industry in Asia make it less likely that these young scientists will be available to work for Massachusetts companies.[24]

Talent is critical to maintaining the Commonwealth's leadership in the life sciences

Industry executives cite the availability of talent as one of the key reasons to locate, maintain and expand operations in Massachusetts.[25] High-quality talent is the Commonwealth's most important advantage over

[22] MassInsight Corporation, 2008.
[23] John Adams Innovation Institute, 2008; PricewaterhouseCoopers, 2007.
[24] MassInsight Corporation, 2008.
[25] Massachusetts Life Sciences Collaborative, unpublished survey data, 2008; Nakajima and Loveland, 2007, PricewaterhouseCoopers, 2007.

competitor states and nations, which offer industry lower costs for site acquisition, taxes, cost of living and other key business factors.

Research conducted for this report and other recent studies suggests that Massachusetts has the capacity to continue its leadership in the global life sciences industry. However, the Commonwealth's leadership position is in jeopardy unless state government, educational institutions and industry find new ways to coordinate their efforts and collaborate to educate and train tomorrow's scientists, engineers and business leaders.

The Life Sciences Talent Initiative

Overview

Massachusetts Governor Deval Patrick announced the Massachusetts Life Sciences Initiative in May 2007 to make the Commonwealth the global leader in the life sciences. Ensuring that the state has the talent to meet the needs of the growing life sciences sector is critical to the success of the Initiative, which is led by the Massachusetts Life Sciences Center, a quasi-public agency of the Commonwealth of Massachusetts created by the Massachusetts legislature in June 2006.

The Life Sciences Talent Initiative was the first project funded by the Massachusetts Life Sciences Center in partnership with the Massachusetts Biotechnology Council. LSTI was designed as a comprehensive study to inform a collaborative statewide strategy among business, government and higher education to ensure that the state's talent needs in the life sciences are met. It provides a systematic analysis of current and future talent needs of the industry and the capacity of higher education to respond to those needs.

Project Leadership

LSTI was lead by a steering committee representing the Massachusetts Life Sciences Center, the Massachusetts Biotechnology Council, the University of Massachusetts, the Massachusetts Biotechnology Education Foundation, the Massachusetts Medical Device Industry Council, the Massachusetts Executive Offices of Housing and Economic Development and Labor and Workforce Development, Commonwealth Corporation, and the Massachusetts Life Sciences Collaborative.

Additional guidance was been provided by:

- An advisory committee comprised of representatives of leading biopharmaceutical and medical device companies and academic hospitals; state executive agencies; the Massachusetts legislature; and public and private higher education institutions, chaired by Zoltan Csimma, Senior Vice President and Chief Human Resources Officer, Genzyme;
- An academic task force comprised of life sciences faculty representing more than twenty public and private Massachusetts colleges and universities; chaired by George Langford, formerly the Dean of the College of Natural Sciences and Mathematics, UMass Amherst;
- A panel comprised of workforce training professionals, chaired by Nancy Snyder, President and Chief Executive Officer, Commonwealth Corporation.

Research Methods and Data Sources

Project staff gathered information and produced the findings in this technical report through a variety of research methods, including:

- A literature review of current occupational and educational research on the life sciences.
- Quantitative analysis of current life sciences workforce by occupation and projection of occupational growth through 2014 using federal and state data sources.
- Qualitative analysis of the current workforce and anticipated future growth, based on interviews and focus groups with industry leaders and a web-based survey of human resource professionals, representing more than 100 life science employers with a presence in Massachusetts. Collectively, the interviews, focus groups and survey gathered perspectives from experienced professionals in every sector of the industry, including medical device, biotechnology and pharmaceutical companies, contract manufacturers, academic medical and research centers; clinical research organizations, suppliers of instrumentation and other products to the industry, staffing companies and venture capitalists.
- Inventory of post-secondary education and training programs in the life sciences in Massachusetts.
- Identification of successful strategies in other states with a strong life sciences sector.
- Discussion of draft findings and implications for state policy, industry leadership and action by educational and training institutions at a statewide summit attended by nearly 300 leaders from industry, government and higher education.

Data gathered from all of these sources were integrated to develop findings and draft recommendations, which were presented to the project Steering Committee, Advisory Committee, Academic Task Force and Workforce Panel. Recommendations were revised based on comments from members of these groups. A diagram and timeline describing the LSTI process are shown in Appendix B.

The conclusions presented in this report reflect an iterative process of engaging the knowledge and experience of a very broad group of high-level representatives of the Massachusetts life sciences industry, state government, two-year and four-year colleges and universities and the workforce training system. Over the course of a year, the Life Sciences Talent Initiative built connections between life sciences employers, education and training institutions and state agencies. Implementation of recommendations to address the life science industry's need for talent will require more extensive involvement, collaboration and cooperation by and between these stakeholders.

The Massachusetts Life Sciences Center was established to support statewide, comprehensive strategies to maintain the Commonwealth's national leadership in life sciences research, innovation and employment.[26] This report, commissioned by the Center, offers recommendations on policies, programs and directions to ensure Massachusetts continues to serve as both a generator of and magnet for talent in the biomedical life sciences. The Life Sciences Center has a unique opportunity to convene the key players who will be integral to implementing these recommendations, and to leverage the resources needed to move forward.

[26] Massachusetts General Laws Chapter 23I, Section 1, Paragraph 10.

INDUSTRY NEEDS

Industry Needs: Current and Future Life Sciences Workforce

Occupational Data Analysis: Methodology

Industry Definition

LSTI's quantitative analysis uses federal and state occupational and employment data to summarize current and historical employment and project future occupational growth for the life sciences cluster.

For the purposes of this study, the life sciences industry is defined as encompassing commercial biomedical activities as well as non-commercial scientific research and development activities taking place in universities and hospitals.[27] In accordance with this definition, project staff identified three major sectors of life sciences industry activity in Massachusetts: Biopharmaceuticals, Medical Devices, and Scientific Research and Development. In contrast to some definitions of the life sciences industry, this definition excludes medical service activities, such as medical and diagnostic testing laboratories.

The tables below illustrate the North American Industry Classification System (NAICS) codes affiliated with each of the three life sciences sectors.

Table 2: Biopharmaceuticals sector of life sciences industry

NAICS Code	Description
3254 (partial as follows)	Pharmaceutical and Medicine Manufacturing
325411	Medicinal and Botanical Manufacturing
325412	Pharmaceutical Preparation Manufacturing
325413	In-Vitro Diagnostic Substance Manufacturing
325414	Biological Product (except Diagnostic) Manufacturing

[27] Industry definition was developed by consulting a number of recent life sciences studies produced by the UMass Donahue Institute as well as a full range of other research groups doing research on the life science industry. See Appendix C and Works Consulted for more information.

Table 3: Medical devices sector of life sciences industry

NAICS Code	Description
334510	Electromedical and electrotherapeutic apparatus manufacturing
334517	Irradiation apparatus manufacturing
339111	Laboratory apparatus and furniture manufacturing
339112	Surgical and medical instrument manufacturing
339113	Surgical appliance and supplies manufacturing
339114	Dental equipment and supplies manufacturing
339115	Ophthalmic goods manufacturing
339116	Dental laboratories

Table 4: Scientific research and development sector of life sciences industry

NAICS Code	Description
611310* (partial)	Colleges, universities and professional schools
6221* (partial)	Teaching hospitals and research institutions
541380* (partial)	Testing laboratories
54171** (partial)	Research and development in the physical, engineering, and life sciences
5417102	Research & development in the life sciences

* Apportionment determined by applying life sciences specific filter to occupational information

* Apportionment for life sciences R&D is .561 percent of employment in 54171

Critical and Core Occupations Included in the Life Sciences Sector

As other studies have observed, the broadly defined standard occupational codes (SOC) used by the federal government to maintain statistics on employment do not precisely align with actual occupations in the rapidly-evolving global life sciences industry. There are also regional differences in employment within the industry that are not reflected in SOC codes.

An industry-specific method of defining and classifying life sciences occupations has been developed by Radford Surveys + Consulting for the primary purpose of collecting data on compensation and business practices. A recent study by the San Diego Workforce Partnership funded by the U.S. Department of Labor established a crosswalk linking the standard occupational codes used for all industries with the Radford Surveys + Consulting occupations specific to the life sciences industry. Researchers then used the crosswalk to analyze and project national labor market trends in the life sciences.[28] This is a new approach to labor market analysis in the industry that has not yet been adopted by other researchers, and has not been used to examine statewide or regional industry trends. Occupations defined within this system appear to be weighted toward the biotechnology, pharmaceutical and medical research sectors of the industry, and may not reflect job descriptions within the medical device sector with equal specificity.

[28] San Diego Workforce Partnership, 2006.

Due to limitations of time and resources and the desire to apply a standard academic methodology, UMass Donahue Institute researchers used SOC codes that provide a reasonable match to industry employment in the Commonwealth for the purpose of the occupational analysis conducted for the Massachusetts Life Sciences Talent Initiative. In the future, it would be valuable to determine whether the SOC-Radford crosswalk could be used to provide a more precise analysis and projection of employment in the industry in Massachusetts.

Researchers analyzed the frequency of all SOC occupations within the biopharmaceutical, medical device and scientific R & D segments of the industry as defined in Tables 2, 3 and 4 above, and selected all occupations that make up at least 2 percent of employment in any NAICS code fully included in these industry definitions.[29] ***Occupations that meet the 2 percent criterion were considered to be "critical" life sciences occupations for the purposes of the study.*** NAICS codes that are only partially included in the definition of the industry—colleges and universities, teaching hospitals and research institutions, and medical and diagnostic laboratories—were not used to generate the list of life sciences occupations. A list of the 112 critical occupations is included in Appendix D; this list includes scientists and technicians as well as commercial, administrative and support functions essential to the industry.

UMDI also conducted a literature review of life sciences occupations in clusters across the United States to identify a set of "core" life sciences occupations. These core professions require specific scientific or technical knowledge and skills directly related to the industry.

Core life sciences occupations are a subset of the 112 critical occupations, and include the following:

- **Biomedical Engineers**
- **Biochemists and Biophysicists**
- **Microbiologists**
- **Medical Scientists, except Epidemiologists**
- **Life Scientists, all other**
- **Biological Technicians**
- **Chemical Technicians**
- **Life, Physical, and Social Science Technicians, all other**

Definitions of these eight core occupations from the Bureau of Labor Statistics are included in Appendix D.

All Massachusetts workers in the eight *core* occupations are considered to be life sciences workers regardless of the actual setting where they are employed. However, occupational projections were done only for workers employed in core occupations *in life sciences sectors*. Workers currently employed in the eight core occupations in *other* sectors of the economy, such as the defense industry, appear in aggregate on the last row of Table 27 in Appendix D. All Massachusetts workers in *critical* occupations in the biopharmaceutical, medical device and life sciences research and development sectors are also considered to be life sciences workers.

To estimate employment of life sciences workers in academia, teaching hospitals and research institutions, testing laboratories and types of R & D, UMDI identified the percentage of employees in these sectors that are *core* life sciences workers, and then applied this percentage to all 112 critical occupations. For the purposes of this analysis, approximately 4.6 percent of higher education workers, 3.3 percent of workers in testing and diagnostic laboratories and 1.5 percent of hospital workers in Massachusetts are considered to be life sciences workers.

[29] Occupations were selected at the 6-digit Standard Occupational Code level; life sciences sub-sectors were defined at the 4-digit NAICS code level.

Researchers compiled data on 2006 employment in core and critical life sciences occupations, and developed occupational growth projections for these occupations through 2014. Due to restrictions on the data designed to protect the confidentiality of individual firms, approximately 14 percent of workers in the life sciences industry could not be identified by occupation. To estimate the distribution of these workers by occupation, researchers used percentages of persons employed in the 112 critical occupations for the 80 percent of workers in the industry for which data is available.

The occupational growth projections that follow rely heavily on the work of the Massachusetts Department of Labor and Workforce Development (DLWD) and the US Bureau of Labor Statistics (BLS) and follow a standard approach that is widely utilized by labor economists and workforce analysts. They are based on:

- BLS projections of the production levels of U.S. industry sectors total output of goods and services;
- BLS projections of the number of jobs that will be needed in the industries to produce those goods and services;
- BLS and DLWD analyses of the current size of the Massachusetts labor pool and projections of changes in the state's population and labor force;
- BLS knowledge about industry dynamics—the mix of occupations that will be in demand is determined both by the amount of goods and services produced and by the ways in which industries produce them;
- DLWD adjustments made to BLS projections to approximate Massachusetts industry conditions.

Limitations of the Analysis

Occupational growth projections are not scientific predictions of future employment growth in the life sciences industry in Massachusetts. The state's life sciences sector is a young and dynamic industry, and is evolving rapidly in the context of a global economy with many states and nations competing to attract and retain firms and workers in the cluster. Projections do not consider many factors that will influence the growth and development of the industry in the Commonwealth, including:

- The impact of future business relocations in and out of the state;
- The impact of future layoffs due to product failures, mergers, buyouts and other business changes;
- Unanticipated changes in industry dynamics, such as technological developments;
- Industry responses to state policy initiatives;
- Investment and incentives offered by other states and nations that could affect job growth in Massachusetts.

Occupational projections represent estimated net growth. They cannot be used to determine the number of existing jobs that will become vacant due to departure of current workers in Massachusetts life sciences firms as a result of career changes, dismissals, relocations, retirement and death. While there is currently no rigorous method to estimate the vacancy rate or churn of workers across the Massachusetts life sciences industry, findings from the focus groups, interviews and surveys conducted for the Life Sciences Talent Initiative provide some indication of the functional areas where employers are struggling to find qualified staff.

Finally, occupational projections do not consider the impact of growth in the life sciences industry on other sectors in the Massachusetts economy to the extent that jobs in non-core occupations are created in firms outside of the NAICS codes listed in Tables 2, 3 and 4. Thus, while projections include increased demand for lawyers, accountants and human resource managers employed by biopharmaceutical and medical device companies, they do not include projections of increased employment in outside law and accounting firms and job recruiters due to services demanded by a growing life sciences industry.

Occupational Data Analysis: Findings

The life sciences sector is growing faster than the Massachusetts economy as a whole

Table 5 shows 2006 employment and projected occupational growth through 2014 for broad categories of life sciences workers. 2006 employment of approximately 100,000 workers in critical occupations in the industry is expected to increase by slightly more than 11 percent over the eight-year period, for an annualized growth rate of 1.3 percent. While projected occupational growth in the industry is slower than historical rates of employment growth in the life sciences, the expected increase is substantially larger than the 0.7 percent increase in occupational growth projected for all Massachusetts industries between 2006 and 2011.[30]

Occupation groups with high projected growth include:

- Computer and Mathematical Occupations: 22.8 percent growth
- Legal Occupations: 20.3 percent growth
- Life, Physical and Social Science Occupations: 16.7 percent growth
- Architecture and Engineering Occupations: 14.5 percent growth.

Table 5: Current employment and projected growth for categories of life sciences workers, 2006-2014

Management Operations	10,861	11.0%	1,061	9.8%	1.18%
Business and Financial Operations Occupations	6,016	6.1%	803	13.3%	1.57%
Legal Occupations	3,575	3.6%	726	20.3%	2.34%
Sales and Related Occupations	2,405	2.4%	183	7.6%	0.92%
Healthcare Practitioners and Technical Occupations	1,173	1.2%	157	13.4%	1.58%
Office and Administrative Support Occupations	12,526	12.6%	91	0.7%	0.09%
Nursing, Psychiatric, and Home Health Aides	402	0.4%	42	10.4%	1.24%
Education, Training and Library Occupations	247	0.2%	37	15.1%	1.77%
Production Occupations	11,708	11.8%	13	0.1%	0.01%
Total All Sectors	**99,157**	**100.0%**	**11,069**	**11.2%**	**1.3%**
* Assumes occupations for which detailed data are not available will grow at the same rate as the sector overall.					

[30] New England Economic Partnership, 2007.

Table 6 provides information on current employment and growth for the top 25 critical occupations in the life sciences by number of employees.

Table 6: Current employment and projected growth for top 25 critical occupations in life sciences

Occupation	2006 Population in Life Sciences Sectors	Occupation as Percent of Total Life Sciences Sector	Projected Increase in Demand, 2006-2014	Projected 8-year (2006-2014) Growth	Projected Annual Growth
Medical Scientists	3,672	3.7%	917	25.0%	2.8%
Computer Software Engineers, Systems Software	2,555	2.6%	707	27.7%	3.1%
Lawyers	2,771	2.8%	579	20.9%	2.4%
Computer Systems Analysts	2,017	2.0%	537	26.6%	3.0%
Computer Software Engineers, Applications	1,889	1.9%	520	27.5%	3.1%
Biochemists & Biophysicists	1,454	1.5%	421	28.9%	3.2%
Life, Physical & Social Science Technicians	3,621	3.7%	373	10.3%	1.2%
Electrical Engineers	2,095	2.1%	278	13.3%	1.6%
Accountants & Auditors	1,845	1.9%	264	14.3%	1.7%
Management Analysts	1,510	1.5%	250	16.6%	1.9%
Biomedical Engineers	685	0.7%	243	35.6%	3.9%
General & Operations Managers	2,334	2.4%	225	9.6%	1.2%
Electronics Engineers, except Computer	1,089	1.1%	211	19.4%	2.2%
Mechanical Engineers	1,495	1.5%	194	13.0%	1.5%
Network Systems & Data Communications Analysts	321	0.3%	189	58.9%	6.0%
Industrial Engineers	1,150	1.2%	186	16.2%	1.9%
Electrical & Electronic Engineering Technicians	1,478	1.5%	186	12.6%	1.5%
Engineering Managers	1,254	1.3%	177	14.1%	1.7%
Biological Technicians	1,192	1.2%	173	14.5%	1.7%
Business Operations Specialists, All Other	1,085	1.1%	171	15.8%	1.8%
Sales Representatives, Wholesale & Manufacturing, Technical & Scientific Products	2,241	2.3%	163	7.3%	0.9%
Executive Secretaries & Administrative Assistants	2,057	2.1%	163	7.9%	1.0%
Team Assemblers	2,416	2.4%	163	6.7%	0.8%
Network & Computer Systems Administrators	544	0.5%	149	27.4%	3.1%
Paralegals & Legal Assistants	804	0.8%	146	18.2%	2.1%

Life sciences industry requires a highly educated workforce

The list of rapidly growing occupations reflects the highly skilled and professional nature of the workforce in the Massachusetts life sciences industry. Table 7 shows education and training requirements for the expected increase in demand for the 112 critical occupations in the industry. More than 80 percent of these new positions will require a minimum of a four-year degree, and at least a third will require a graduate degree, work experience, or both.

Table 7: Typical requirements for education or training, 112 critical life sciences occupations

Education Requirement*	Projected Occupational Growth 2006-2014	Percent of Total Projected Occupational Growth
Work Experience in a Related Occupation	69	0.7%
Short-Term on-the-job Training	-154	-1.6%
Moderate-Term on-the-job Training	463	4.9%
Long-Term on-the-job Training	8	0.1%
Associates Degree	1,355	14.4%
Postsecondary Vocational Award	4	0.0%
Bachelors Degree	4,218	44.9%
Bachelors or Higher Degree, Plus Work Experience	1,283	13.7%
Doctoral Degree	1,540	16.4%
First Professional Degree	599	6.4%
Bachelors Degree or Higher	**7,640**	**81.4%**
Total (for occupations with detailed data)	**9,385**	**100%**

Source: U.S. Bureau of Labor Statistics. An occupation is placed into one of 11 categories that best describes the postsecondary education or training needed by most workers to become fully qualified in the occupation.

Significant dependence on foreign workers in key occupations

Table 8 shows the percentage of non-citizens in critical life sciences occupational categories that exceed the population of non-citizens in the Massachusetts workforce as a whole. It is worth noting that the occupation with the highest percentage of non-citizens, medical scientists, is also the fastest-growing occupation in the industry.

Table 8: Foreign workers in critical life sciences occupations, 2006

Occupation Group	% Non-U.S. Citizens	Non-U.S. Citizen 95% Margin of Error
Medical scientists	37.5%	11.3%
Computer engineers	21.5%	4.8%
Assemblers	14.9%	4.3%
Biological scientists and technicians and chemists	12.9%	8.4%
Physicians and Surgeons	9.7%	3.9%
Computer and Network Specialists and Analysts	9.6%	2.4%
Engineers	8.1%	3.0%
Chemical and misc. technicians	7.8%	6.2%
MA All Occupations	7.3%	0.2%

Source: Bureau of Labor Statistics, American Community Survey, PUMS 2006

Industry Perspectives: Methodology

Focus Groups and Interviews

Industry perspectives on current and future talent needs in the Massachusetts life sciences industry are based on a series of focus groups and interviews conducted in fall 2007 and an electronic survey of employers conducted in winter 2008.

LSTI researchers conducted five focus groups with employers in the biopharmaceutical industry, two groups with medical device industry professionals, one group with life sciences investors, one group with a mix of life sciences employers and one group with workforce training professionals. Focus group participants were recruited in consultation with members of the LSTI Steering and Advisory Committees. In addition, ten individual interviews were conducted with chief executive officers of a diverse group of companies in the life sciences industries. Lists of focus group members and participants in executive interviews are included in Appendix E.

Employer Survey

UMass Donahue Institute researchers drafted an electronic survey for human resources professionals in the life sciences industry in Massachusetts in consultation with members of the project Steering Committee and Advisory Committee. A copy of the survey text is included in Appendix F.

The survey link was provided to four industry associations, which distributed the survey to their members in early January as follows:

- Massachusetts Biotechnology Council: distributed to more than 400 human resource professionals
- Massachusetts Medical Device Industry Council: distributed to 220 primary contacts at manufacturing firms
- Massachusetts Society for Medical Research: distributed to 26 companies
- Biomedical Engineering Alliance and Consortium: distributed to 60 companies

UMass Donahue Institute staff also distributed the survey to key executives at nine academic medical centers. In most cases, the survey was sent to the senior employee supervising clinical research operations at the hospitals.

The survey generated usable responses from 76 discrete employers. Figure 6 shows respondents by the location of their facilities in Massachusetts.

Figure 6: LSTI survey respondents by location of Massachusetts facilities

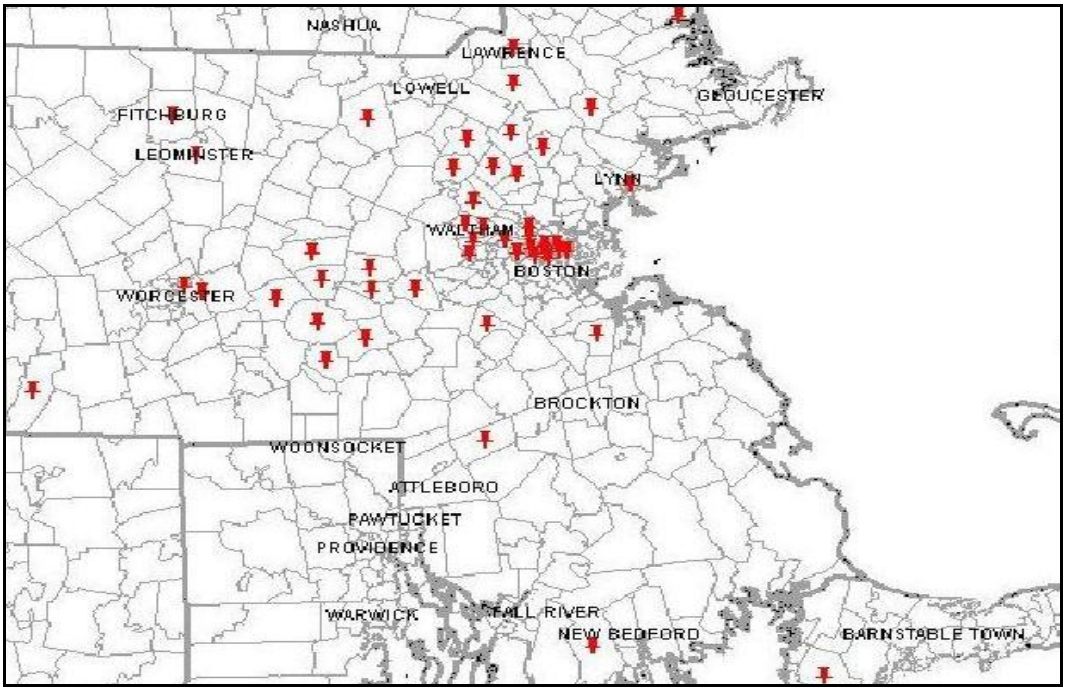


Table 9 shows respondents by industry sector. Respondents could check more than one sector, so the categories are non-exclusive.

Table 9: LSTI survey respondents by sector

Which of the following best describes the focus of your organization's Massachusetts-based operations? (Please check all that apply)	Response Count	Response Percent
Medical devices	38	52.1%
Biotechnology	23	31.5%
Pharmaceuticals	15	20.5%
Other	9	12.3%
Contract manufacturer	6	8.2%
Academic medical center	4	5.5%
Contract research organization, non-clinical	4	5.5%
Academic research center	3	4.1%
Reagents and instrumentation	2	2.7%
Contract research organization, clinical	1	1.4%
Supplier of other products or services to the life sciences industry	1	1.4%
Staffing company	0	0.0%
answered question		***73***

Table 10 provides a breakdown of survey respondents by the activities that their companies conduct in Massachusetts.

Table 10: LSTI survey respondents by company activities in Massachusetts

Which of the following functions does your organization perform or operate in Massachusetts? Please check all that apply.	Response Count	Response Percent
Research	58	77.3%
Product design and development	50	66.7%
Company headquarters - World	36	48.0%
Sales and marketing	35	46.7%
Manufacturing - Pilot scale	29	38.7%
Manufacturing - Commercial scale	24	32.0%
Human clinical trials	21	28.0%
Company headquarters - United States	20	26.7%
Animal product testing	17	22.7%
Company headquarters - Corporate division	10	13.3%
Other	5	6.7%
answered question		***75***

Most of the survey respondents represented relatively small companies. Table 11 shows survey respondents by number of full-time equivalents.

Table 11: LSTI survey respondents by number of employees

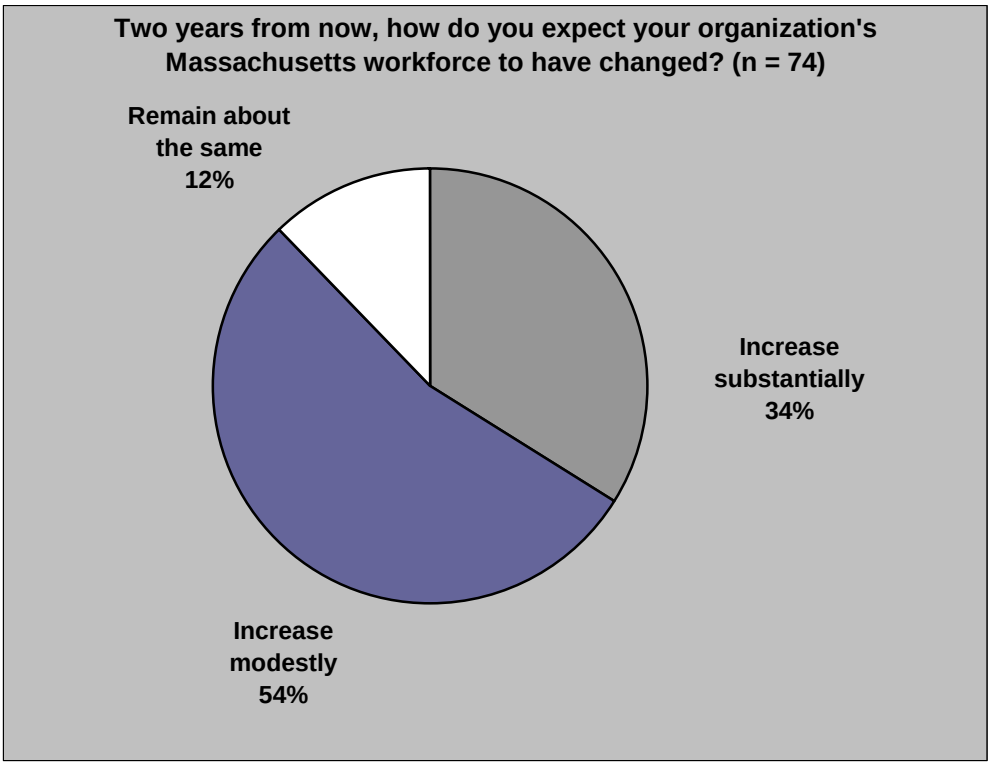
Number of full-time equivalent employees in Massachusetts	Number of companies	Response %
1 - 50	49	72.1%
51 - 200	10	14.7%
201 - 500	3	4.4%
501 - 1000	4	5.9%
more than 1000	1	1.5%
Answered question		***70***
Usable responses		***68***

Industry Perspectives: Findings

Employers expect Massachusetts workforce to grow

The majority of employers interviewed and surveyed by the Life Sciences Talent Initiative emphasized that the Massachusetts workforce is a strength for the life sciences industries. A majority of survey respondents expected their Massachusetts operations to grow over the next two years.

Figure 7: Employment growth projections, LSTI survey



Current operations and continued growth depend on highly education workers

Survey results support the finding that the Massachusetts life sciences workforce is highly educated. While approximately 75 percent of survey respondents reported that their current workforce includes employees with less than a bachelor's degree, these workers were a minority of the total workforce. Employers estimated that more than 75 percent of their current Massachusetts labor force has at least a bachelor's degree.

Table 12: Estimated percentages of Massachusetts workforce by level of education, LSTI survey respondents

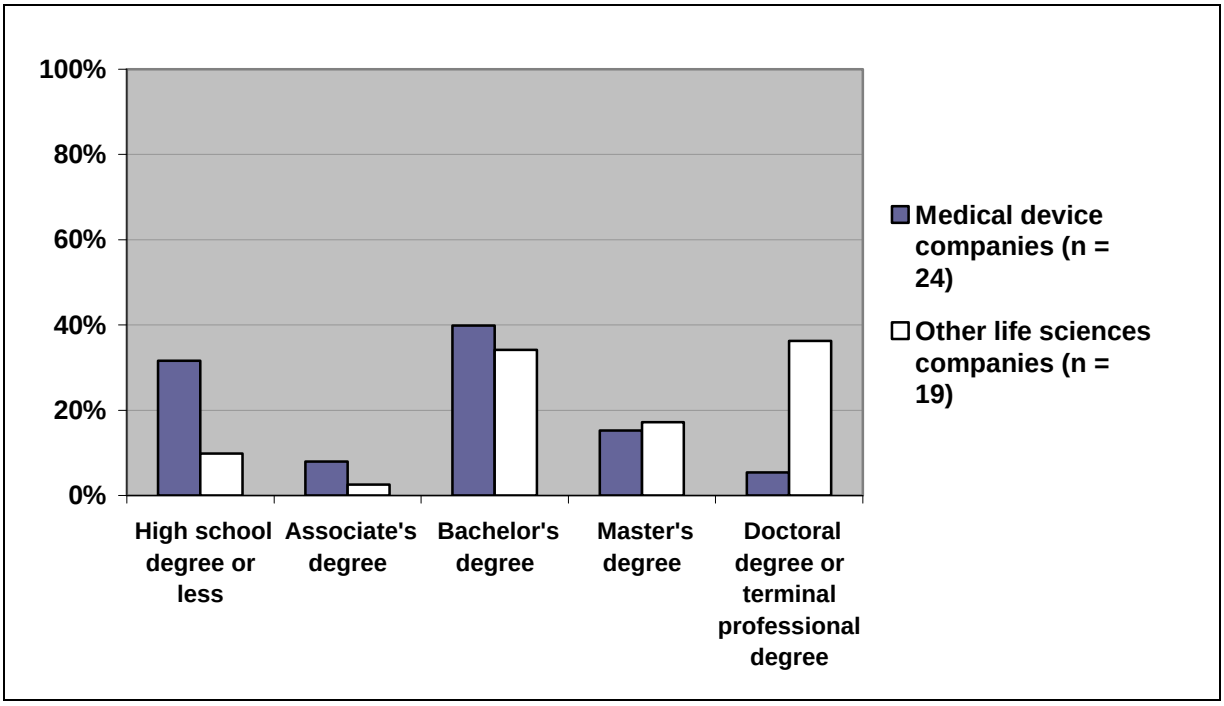
Level of education	Average % of workforce in category (average of employer estimates)
High school degree or less	19.2%
Associate's degree	5.2%
Bachelor's degree	38.7%
Master's degree	15.3%
Doctoral or terminal professional degree	21.6%
Bachelor's degree or higher, total	**75.6%**
answered question	***62***
usable responses (answers totalled 100%)	***55***

Participants in focus groups and interviews also reported limited demand for workers with less than a four-year degree. While most of the employers represented employ technicians with lower levels of education, they generally reported that the pipeline of these workers is currently adequate, and that the trend in manufacturing is

toward more complex processes that will likely require a four-year degree in the future. This finding was echoed by workforce training professionals, who said that existing programs to train life sciences technicians seem to be meeting the demand for workers in the field.

Medical device firms appear to offer more opportunities for workers without a four year degree. Among respondents to the LSTI employer survey, 79 percent of medical device companies reported hiring workers with high school degrees, compared to only 53 percent of other life sciences firms. Employers in the medical device industry also reported a much higher percentage of their workforce below the four-year degree level, as shown in Figure 8.

Figure 8: Comparison of medical device and other life sciences workforce by level of education, LSTI survey respondents



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Employers face challenges finding the talent they need

While employers in the life sciences fields cited the Massachusetts workforce as a strength, they also expressed concerns about whether the talent pool will be adequate to meet their short and long-term needs. Participants in focus groups, interviews and the survey reported a consistent set of challenges in meeting the need for talent.

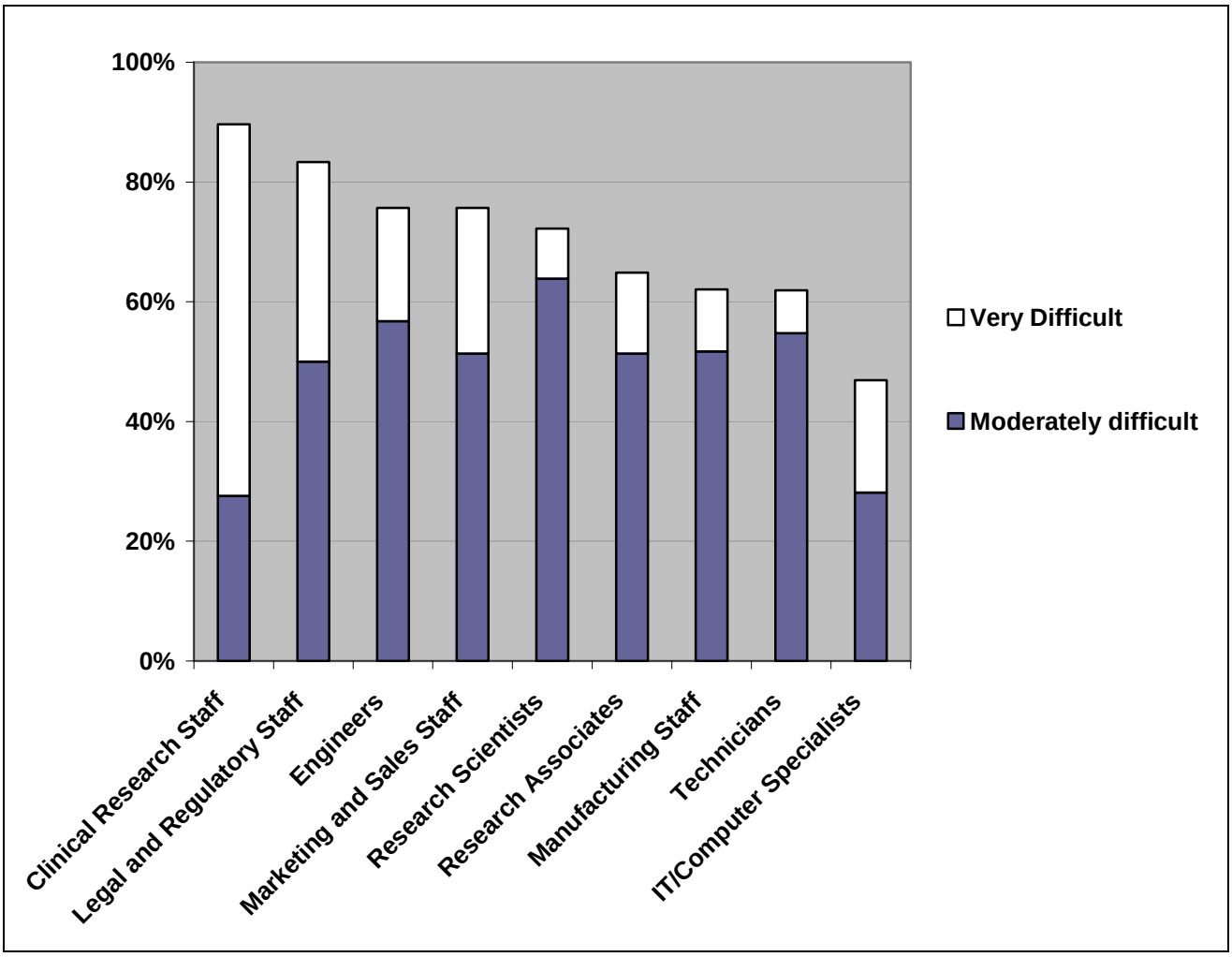
Need for employees with experience

While life sciences companies undoubtedly hire some entry-level workers, most of the employer representatives interviewed and surveyed for the Life Sciences Talent Initiative emphasized the need for employees with previous experience in the industry. Very few of the human resource professionals who participated in focus groups for this study recruit new hires directly from educational programs. Most rely on a combination of jobs postings, professional recruiters and employee networks to recruit experienced staff from other firms in the industry, both within and outside Massachusetts.

Focus group participants described strong competition to hire staff with previous experience in key functional areas, including clinical research management, legal and regulatory affairs, marketing and sales and quality assurance and quality control. Survey respondents reported very similar challenges, as shown in Figure 9. Clinical research represented a particular area of concern for employers, with 62 percent responding that staff in this area are "very difficult" to hire, and 48 percent responding that it is more difficult to find clinical research staff than it was two years ago.

Some industry analysts argue that shortages of employees in these areas represents good news for Massachusetts, because it is demonstrates the evolution of companies in the Commonwealth from a focus on early-stage research and development to functions further down the value chain in clinical trials, regulatory approval and product sales and marketing.

Figure 9: Difficulty of hiring staff by functional area, LSTI survey respondents



Survey respondents representing biotechnology and pharmaceutical companies reported more difficulty hiring staff overall than medical device firms. All of the biopharmaceutical firms that responded to the survey indicated difficulty finding clinical research and regulatory staff, and they also reported more difficulty finding engineers, technicians, manufacturing staff and computer specialists than medical device firms, which reported greater difficulty finding research scientists, research associates and marketing and sales employees.

In response to an open-ended question asking employers "what is the most significant challenge to your organization's ability to hire new employees," finding and recruiting personnel with appropriate and often unique life sciences skill sets dominated replies. More than half of the responses to this question addressed difficulty finding staff with the desired expertise, and comments in this category occurred more than twice as often as any other type of challenge. Most responses addressed the difficulty of finding specialty scientific or technical expertise in areas including biologics, diagnostics, medical devices and optics, but some employers also noted the difficulty of finding employees with a combination of business and scientific experience.

Need for employees with specialized academic preparation and training

Participants in focus groups and interviews also reported difficulty hiring employees with academic training in specific fields, including chemistry, pharmacology, engineering, toxicology and laboratory animal medicine. Manufacturing, process and validation engineers were mentioned as being especially difficult to find. A concurrent UMass Donahue Institute study for the Massachusetts Society for Medical Research also found a shortage of veterinarians with training in laboratory animal medicine.[31] Medical device firms reported a growing shortage of skilled machinists.

Cost of living, housing and transportation in Massachusetts

Participants in focus groups and interviews expressed concern about the high cost of living in Massachusetts, especially in Boston and Cambridge. Employers reported that the cost of housing is particularly problematic with respect to recruiting professional staff in their thirties from states and regions with lower costs. One executive reported that 25 to 30 percent of his company's employment offers to experienced workers from out of state are turned down due to the cost of housing in Greater Boston. He continued "when we work with relocation consultants, I tell them, don't take our prospects to neighborhoods in Cambridge, Lexington and Newton, because when they look at prices, we'll lose them." This executive's company spends $600,000 to $700,000 annually on benefits associated with relocating employees. Representatives of companies in Greater Boston said that their younger employees recruited from other states endured very long commutes in order to afford the same quality of housing that they left when they relocated. Several contacts said that Greater Boston and Cambridge were unaffordable for small companies.

The cost of living, however, may be less of a concern than the ability to find employees with the desired combination of education, experience and skills. In response to the open-ended survey question asking about the most significant employee recruitment challenge, only 10 percent of responses addressed cost of living.

Difficulty hiring or retaining non-citizen employees

Focus group and interview participants described the importance of foreign workers to their operations in Massachusetts. Foreign workers appear to be concentrated in two types of positions: professional scientific and engineering jobs, and manufacturing and laboratory technicians. Employers expressed different concerns with respect to the workers in these two labor pools.

Almost all of the CEOs in the biopharmaceutical and clinical research sector of the industry described the ability to hire non-domestic scientific staff as critical to their business. "We want to be able to hire the best people in the world, no matter where they're from," was a very common theme. Based on the demographics of graduate students in the life and biomedical sciences, chemistry, engineering and computer science, industry representatives emphasized that it is virtually impossible to find the expertise they need without hiring scientists that are not U.S. citizens. CEOs and human resource directors are deeply concerned about the continued availability of highly educated non-domestic workers, based on two recent trends—growing restrictions on H1-B

[31] Loveland et al., 2008.

visas, and increasing opportunities for young scientists in Europe and Asia. Several contacts said that the global availability of scientific workers was one of the factors driving strategic business decisions.

Non-domestic workers are also present in large numbers in technical positions that require a 2-year degree or certificate. "If you go into our factory, it is very much a United Nations," said the CEO of one medical device firm. CEOs and workforce training directors describe immigrant workers in technical fields as mature, well trained and highly motivated. These workers generally have green cards or are citizens, and intend to stay in the United States permanently. However, limited English language skills present a challenge in training and workplace communication.

Locational and immigration issues appear to be less significant obstacles with respect to recruiting high-level scientific talent to Boston and Cambridge. Several CEOs commented that the concentration of premier universities and teaching hospitals in the region, Boston's reputation as a multicultural city and its proximity to Europe make the area a draw for scientific professionals from other countries.

Competitive labor market

Participants in industry focus groups and executive interviews described a highly competitive labor market in the life sciences in Massachusetts, with a mobile and savvy workforce. One professional from a biopharmaceutical firm described this mobility in the Kendall Square neighborhood of Cambridge. "You can have a long career in Cambridge, working at five different companies, and never change your parking spot," he joked.

The competitive hiring environment in the industry presents the greatest challenge for smaller companies, start-ups and firms in the contract research business that find it difficult to match the compensation and benefits offered by large companies, especially those in the biopharmaceutical sector. One representative of a medical device manufacturer suggested that the wage pressure in the eastern part of the state is likely to drive manufacturing to western Massachusetts, other states or offshore.

Hiring entry-level employees and training them presents a special challenge. Several company representatives described situations where they recruited and trained talented young staff, only to lose them to larger companies with deeper pockets and more opportunities for advancement. Many employers expressed concerns about company relocations and expansions in Massachusetts putting pressure on the existing workforce in the state. One executive said that his company had stopped expanding its Massachusetts workforce in a high-demand field because it could not afford to invest in training employees, only to see them accept better offers from other firms in the industry.

Employer opinions of Massachusetts educational system

K-12 student pipeline in STEM fields

While issues in the primary and second education system were outside the scope of the Life Sciences Talent Initiative, participants in interviews, focus groups and the electronic survey expressed concern about the pipeline of students prepared to pursue higher education in science, technology, engineering and math in Massachusetts. One CEO expressed frustration with the perception that young people see academic work in the sciences as "too hard." She emphasized the need to market careers in the life sciences to students prior to college. "We need to solve the problem of why young people don't see sciences tracks as important enough to try hard enough. We need to make these opportunities relevant to young people."

Employer satisfaction with Massachusetts graduates depends of level of education

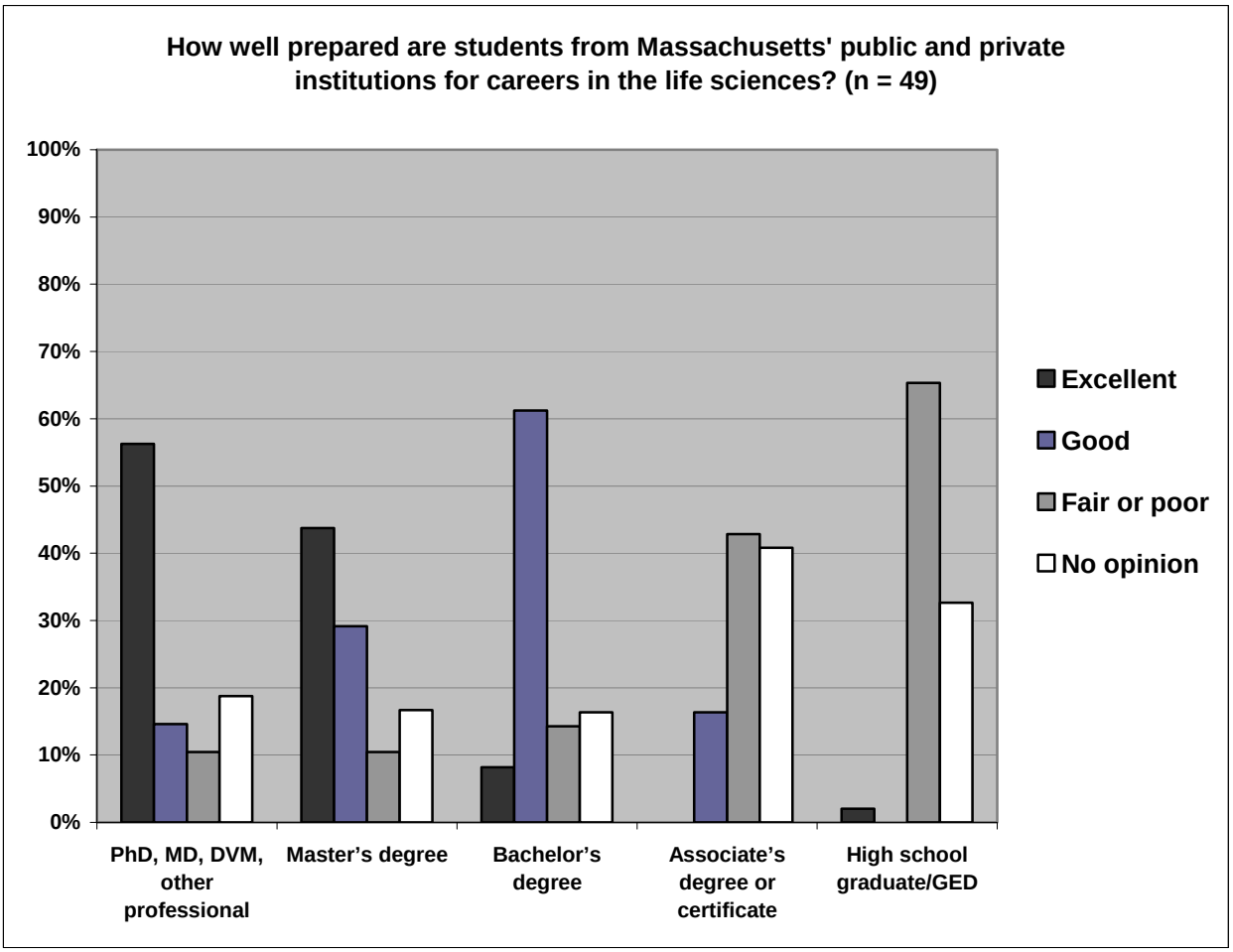
Participants in executive interviews and focus groups reported general satisfaction with Massachusetts graduates with doctoral and professional degrees, but expressed concern that students graduating at the bachelor's degree level and below are not as well-prepared to work in the industry. This finding was echoed by the employer survey, as shown in Figure 10.

Due to the increasing complexity of medical device and biopharmaceutical manufacturing in particular, industry contacts report that they need greater flexibility and adaptability in their workforce. They have addressed this need by hiring at higher levels of education. Jobs that might traditionally have been filled by a high school graduate now generally require some college, and employers are increasingly looking for candidates with advanced degrees where a bachelor's degree might have been acceptable in the past.

The level of education required for manufacturing positions in the life sciences generated a great deal of discussion in focus groups, at the Life Sciences Talent Summit and in meetings of the various advisory boards of the Life Sciences Talent Initiative, but no clear consensus among employers. Industry representatives observed that Massachusetts biopharmaceutical companies hire employees with bachelor's degrees to fill manufacturing jobs that are typically occupied by workers with two-year degrees in other states. Some employers commented that associate's degree programs in North Carolina and California provide excellent training for these positions, and that well-trained workers with two year degrees are likely to stay in manufacturing jobs longer than workers with bachelor's degrees. They suggested that improvements in community college biotechnology programs in Massachusetts could help overcome the bias towards hiring manufacturing staff at the four-year degree level. Other employers argued that biomanufacturing operations in Massachusetts are typically more complex than production in other regions of the country, and thus require employees with more advanced scientific training.

It is important to remember that Massachusetts workers generally have more higher education than their counterparts in other states. While it is possible that the research-intensive nature of the life sciences manufacturing and technical jobs in Massachusetts simply requires workers with advanced education, several industry experts who participated in the Life Sciences Talent Initiative believe that education and training programs below the bachelor's degree could be modified to expand employment opportunities in life sciences sectors and meet industry needs. More work is needed to identify the specific knowledge, attributes and skills required for entry-level life science positions in Massachusetts.

Figure 10: Employer opinions of graduates from Massachusetts schools, LSTI survey respondents

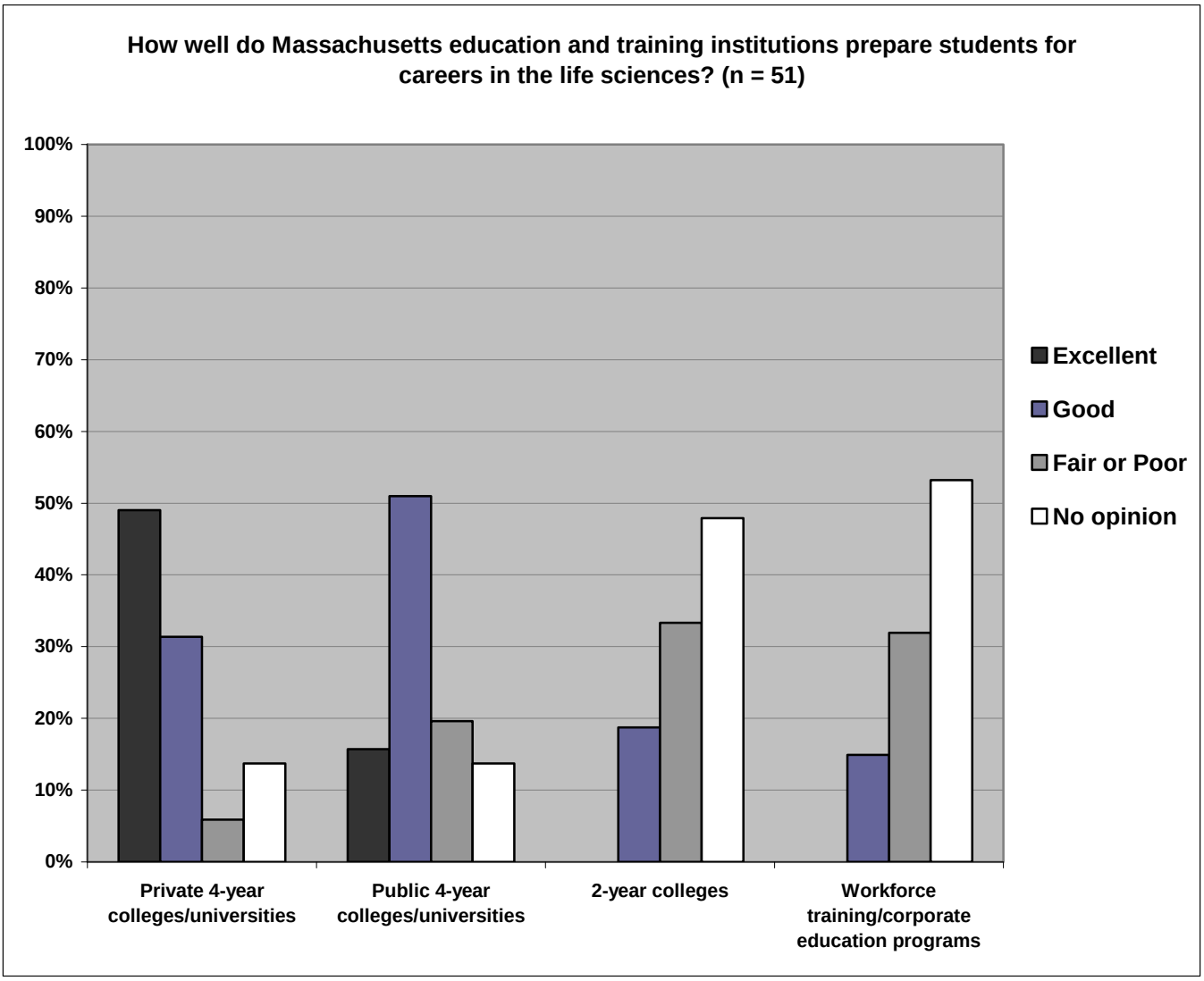


Employer opinions of Massachusetts educational institutions

The LSTI survey asked employers for their opinions of four different types of educational institutions—public four-year colleges and universities, private four-year schools, 2-year colleges, and corporate education and workforce training programs. Responses to this question, as shown in Figure 11, suggest that employers are most familiar with institutions and programs offering education at the bachelor's degree level and above. Nearly half of the 51 employer representatives who responded to this question had no opinion of 2-year colleges, and more than half had no opinion of corporate education and workforce training programs. This finding can be partially explained by the relatively small size of companies represented by survey respondents, and by the fact that the majority of these small, early-stage companies are focused on science-intensive research, design and development activities.

It is, however, noteworthy that among survey respondents who had opinions of two-year colleges, none felt that they did an excellent job of preparing graduates for careers in the life sciences, and fewer than 20 percent thought that two-year schools were doing a good job. Workforce training programs ranked even lower, with only 15 percent of responses in the "good" category.

Figure 11: Employer opinions of Massachusetts education and training institutions, LSTI survey



Survey respondents were most satisfied with graduates from private 4-year schools. Survey responses to an open-ended question asking which private colleges and universities in Massachusetts provide the best education for life sciences careers are shown in Table 13. Focus group participants also cited MIT, Harvard, Northeastern University, WPI and Boston University for excellence in life sciences education; although some thought that this was due in part to the selectivity of these institutions.

Table 13: Best 4-year private schools for life sciences careers, LSTI survey

Which private colleges and universities provide the best education and training for the life sciences in Massachusetts? (open-ended question, list up to 3 schools)	
Institution	**% of responses**
Massachusetts Institute of Technology	86.05%
Harvard University	34.88%
Northeastern University	32.56%
Worcester Polytechnic Institute	32.56%
Boston University	30.23%
Tufts University	18.60%
Boston College	9.30%
Brandeis University	2.33%
Harvard Medical School	2.33%
Wentworth Institute of Technology	2.33%
Total Respondents	***43***

Survey respondents were also relatively satisfied with public 4-year colleges and universities in Massachusetts, with approximately 2/3 of respondents ranking them as either "good" or "excellent" in preparing students for life sciences careers. This rating is largely based on the strength of the University of Massachusetts, as shown in Table 14.

Table 14: Best 4-year public schools for life sciences careers, LSTI survey

Which public colleges or universities in Massachusetts provide the best education and training for careers in the life sciences? (Please select up to three (3) schools from list provided)	
Institution	**% of responses**
University of Massachusetts - Amherst	67.4%
University of Massachusetts Medical School	46.5%
University of Massachusetts - Lowell	39.5%
University of Massachusetts - Boston	32.6%
Worcester State College	20.9%
Salem State College	9.3%
Bridgewater State College	7.0%
Framingham State College	7.0%
University of Massachusetts - Dartmouth	7.0%
Massachusetts Maritime Academy	2.3%
Total Respondents	***43***

Only 25 survey respondents offered a general opinion about 2-year colleges, and only 19 expressed opinions about which community colleges offered the best education and training for life sciences careers. Massachusetts Bay Community College received the most responses to this question with 9 votes, followed by Middlesex and Bunker Hill Community Colleges, with 7 and 6 votes respectively.

EDUCATIONAL CAPACITY

Trends in Higher Education in Life Sciences

In 2003, the National Research Council called for a fundamental transformation of undergraduate science education to prepare a new generation of research biologists. The Bio2010 report recognized the critical importance of knowledge and methods from the physical sciences and mathematics to scientific inquiry in biology. The report warned that conventional undergraduate biology education was no longer adequate to prepare students for careers in science or research. The authors reported:

> Life sciences majors must acquire a much stronger foundation in the physical sciences (chemistry and physics) and mathematics than they now get. Connections between biology and the other scientific disciplines need to be developed and reinforced so that interdisciplinary thinking and work become second nature. Connections within biology are equally important and the relevance of fields such as population biology, plan biology, and cognitive science to biomedical research should not be ignored. Equally important, teaching and learning must be made more active to engage undergraduates, fully prepare them for graduate study, and give them an enduring sense of the power and beauty of creative inquiry.[32]

The Bio2010 report recommended the development of new materials and approaches for undergraduate biological science programs, interdisciplinary laboratory courses, and seminars highlighting cutting edge developments in biology.[33]

Educators and scientists in leading research universities have heeded the call to develop undergraduate science curricula integrating biology with critical concepts and methods from physical and quantitative sciences. Recent articles highlight new introductory science courses at Columbia, Harvard and Princeton Universities.[34] The three universities took very different approaches to developing an integrated science curriculum. Columbia's introductory "Frontiers of Science," class is part of the required undergraduate core curriculum. Harvard created an introductory two-semester integrated life sciences course that is a prerequisite for most life science concentrations. Princeton developed a sequence of three intensive integrated science courses for first- and second-year students who plan careers in research biology and/or the life sciences industry.[35] While the courses have different target audiences, they share a philosophy of teaching science through concepts and approaches to solving problems across disciplines rather than as a collection of facts within isolated fields of knowledge.[36] While the courses have been successful, they have required significant investment of resources to coordinate teaching responsibilities across multiple departments, and to provide support for students with diverse backgrounds and capabilities in science and mathematics.[37]

Other recommendations to improve higher education in the life sciences include promoting active problem-solving and team learning, and encouraging students to pursue independent research early in their college

[32] National Research Council, 2003.
[33] National Research Council, 2003.
[34] Bialek and Botstein, 2004; Arnaud, 2006.
[35] Arnaud, 2006.
[36] Arnaud, 2006.
[37] Arnaud, 2006.

careers.[38] There is evidence that science students who solve problems in small teams perform better on exams and pass classes at a higher rate than students in more traditional lecture-style courses.[39] Studies also show that undergraduate research experiences sustain and increase student interest in post-graduate studies in science and careers in science.[40] Elements of successful undergraduate research programs include dedicated faculty time and laboratory facilities, academic credit and financial support for students, student research seminars and a central office dedicated to promoting undergraduate research.[41]

At the graduate level, there is a recent trend toward the development of professional science master's (PSM) degree programs that offer graduate education in science or mathematics plus advanced training in informatics and computation, and professional education in business, law and communications. PSM programs are intended to offer a terminal graduate degree for scientists who are planning careers in industry rather than academic research.[42] Since 1997, the Sloan Foundation has supported the development of more than 100 PSM degrees at 45 universities across the nation.[43]

The majority of PSM programs are interdisciplinary and approximately half provide training in fields related to biomedical life sciences. These programs typically have strong relationships with local employers. Industry is generally represented on the advisory boards for PSM programs, and PSM degree students typically complete a cooperative education experience or capstone project with an outside entity in lieu of a thesis. As is the case with most professional graduate degree programs, students typically bear the full cost of tuition and associate expenses.

The number of PSM programs in the U.S. has nearly doubled over the past four years, from 67 in 2004 to more than 120 in 2008.[44] Several states, including but not limited to Arizona, California, Maryland, North Carolina, New York and Pennsylvania have created PSM programs in biomedical life sciences fields in the public university and/or state college systems.[45]

A recent survey of more than 1,000 students who enrolled in 82 PSM programs at 39 higher education institutions in the U.S. and Canada in the fall of 2006 found that more than 46 percent of PSM enrollments were in biosciences or bioinformatics. Programs in these areas accounted for 50 percent of 2006 PSM graduates. The same study reported that more than 73 percent of 2006 graduates from PSM programs in all disciplines were employed in non-academic settings.[46]

[38] Brainard, 2007; National Research Council, 2003.
[39] Beichner and Saul, 2004.
[40] Lopatto, 2004, 2007.
[41] Mateja and Otto, 2004.
[42] Glazer-Raymo, 2005; Council of Graduate Schools, 2008.
[43] Glazer-Raymo, 2005.
[44] Council of Graduate Schools, 2008.
[45] National Professional Science Master's Association, data provided to LSTI staff by Executive Director Stephen Lemire.
[46] Council of Graduate Schools, 2008.

Life Sciences Higher Education and Training in Massachusetts

Structure of Massachusetts life science education and training programs

Institutions and fields of study

In 2006, 85 public and private institutions in Massachusetts awarded a total of 13,226 post-secondary degrees or certificates in 61 life sciences-related fields.[47] Table 15 shows the number of institutions awarding certificates and degrees by level of education, as well as the number of life sciences-related fields of study for each level of education.

Table 15: Massachusetts institutions awarding post-secondary degrees and certificates in life sciences fields by level, 2006

Award Level	Number of Institutions awarding degrees	Number of fields of study
Certificates below the baccalaureate total	22	10
Associate's degree	29	26
Bachelor's degree	58	41
Certificates above the baccalaureate total	4	3
First-professional degree	3	2
Master's degree	30	39
Doctor's degree	14	34
Total	***85***	***61***

Source: National Center for Education Statistics, Integrated Postsecondary Educational Data System

Life sciences-related fields and the number of institutions awarding degrees and certificates by field are shown in Table 16. Degrees in life sciences-related fields constituted 13.7 percent of all higher education degrees awarded in Massachusetts in 2006.[48] In comparison, the same fields of study accounted for 13.2 percent of all higher education degrees awarded in the United States in the same year.

[47] National Center for Educational Statistics, Integrated Postsecondary Educational Data System. See Table 16 and Appendix G for more information on life sciences fields. Health science degrees, such as MDs, DVMs and RNs are not included in totals.
[48] National Center for Educational Statistics, Integrated Postsecondary Educational Data System, certificates not included.

Table 16: Life sciences fields and number of institutions awarding degrees by field, Massachusetts, 2006

Field of Study	Number of institutions awarding degree in field
Computer and information sciences and support services.	134
Biology, General	72
Chemistry	66
Mathematics and statistics.	65
Physics	54
Biochemistry, Biophysics and Molecular Biology	33
Electrical, Electronics and Communications Engineering	31
Mechanical Engineering	27
Electrical Engineering Technologies/Technicians	22
Neuroscience	18
Chemical Engineering	17
Computer Engineering, General	17
Ecology, Evolution, Systematics and Population Biology	17
Clinical/Medical Laboratory Science and Allied Professions	16
Drafting/Design Engineering Technologies/Technicians	16
Biotechnology	15
Mechanical Engineering Related Technologies/Technicians	15
Engineering, General	13
Biomedical/Medical Engineering	12
Industrial Production Technologies/Technicians	12
Cell/Cellular Biology and Anatomical Sciences	11
Computer Engineering Technologies/Technicians	11
Electromechanical Instrumentation and Maintenance Technologies/Technicians	11
Pharmacy, Pharmaceutical Sciences, and Administration	11
Biological and Biomedical Sciences, Other	10
Industrial Engineering	10
Biomathematics and Bioinformatics	8
Engineering, Other	8
Engineering Science	7
Manufacturing Engineering	7
Microbiological Sciences and Immunology	7
Pharmacology and Toxicology	6
Physiology, Pathology and Related Sciences	6
Engineering-Related Fields	5
Materials Engineering	5
Medical Clinical Sciences/Graduate Medical Studies	5
Biological and Physical Sciences	4
Biology Technician/Biotechnology Laboratory Technician	4
Engineering Technologies/Technicians, Other	4
Engineering Technology, General	4
Mathematics and Computer Science	4
Systems Engineering	4
Engineering Physics	3
Genetics	3
Operations Research	3
Physical Science Technologies/Technicians	3
Polymer/Plastics Engineering	3
Quality Control and Safety Technologies/Technicians	3
Systems Science and Theory	3
Botany/Plant Biology	2
Engineering-Related Technologies	2
Natural Sciences	2
Textile Sciences and Engineering	2
Zoology/Animal Biology	2
Engineering Mechanics	1
Science Technologies/Technicians, Other	1
Veterinary Medicine (DVM)	1

Tables 15 and 16 provide an overview of the types of higher education programs in the life sciences in Massachusetts, but do not constitute a comprehensive listing of programs of study available in the Commonwealth.

The Life Sciences Talent Initiative originally intended to catalogue all Massachusetts higher education and workforce training programs and capabilities related to the development of skills that are relevant to participation in the life sciences industry. This turned out to be an unmanageable task due to the number of institutions and programs involved and the fact that a majority of schools did not have a central point of contact that could provide this information. In light of limited time and resources, LSTI researchers focused on assembling an inventory of life sciences education programs offered by the University of Massachusetts, state and community colleges.

A draft inventory was compiled through review of institutional websites and direct contact with faculty and administrators at educational institutions, including members of the LSTI Academic Task Force. Drafts were then sent to administrators at the University of Massachusetts, the Massachusetts State College Council of Presidents Executive Office and the Massachusetts Community College Executive Office for review. Draft program inventories for 27 public higher education institutions are available as a separate appendix to this report.

Ten higher education institutions were responsible for 65 percent of degrees and certificates in life sciences fields in 2006, as shown in Table 17.

Table 17: Post-secondary degrees and certificates awarded in life sciences fields, top ten institutions in Massachusetts, 2006

Institution	Sum of Total Awards
Massachusetts Institute of Technology	1749
Boston University	1409
Northeastern University	1080
University of Massachusetts-Amherst	864
Harvard University	824
Worcester Polytechnic Institute	719
University of Massachusetts-Lowell	635
Tufts University	583
Brandeis University	375
Massachusetts College of Pharmacy & Health Science	356
Total, top ten institutions	***8594***
% of total life sciences awards statewide	***65.0%***

Source: National Center for Education Statistics, Integrated Postsecondary Educational Data System

Life sciences education at public higher education institutions

Massachusetts is unique in being the only state in the nation that educates more students in private higher education institutions than in the public sector, so it is not surprising that public institutions account for a minority of Massachusetts degrees awarded in life sciences-related fields. The five campuses of the University of Massachusetts, eight state colleges and 15 community colleges accounted for approximately 27 percent of degrees and certificates awarded in these fields in 2006, as shown in Table 18.

Table 18: Post-secondary degrees and certificates awarded in life sciences-related fields, public institutions in Massachusetts, 2006

Institution	Sum of Total Awards
University of Massachusetts-Amherst	864
University of Massachusetts-Lowell	635
University of Massachusetts-Dartmouth	253
University of Massachusetts-Boston	177
University of Massachusetts Medical School Worcester	27
% of total awards statewide	***14.8%***
Worcester State College	110
Bridgewater State College	96
Fitchburg State College	78
Framingham State College	59
Salem State College	58
Westfield State College	49
Massachusetts Maritime Academy	41
Massachusetts College of Liberal Arts	24
% of total awards statewide	***3.9%***
Bristol Community College	170
Springfield Technical Community College	161
Northern Essex Community College	129
Quinsigamond Community College	105
Massasoit Community College	90
Middlesex Community College	85
Massachusetts Bay Community College	83
Bunker Hill Community College	72
Mount Wachusett Community College	70
North Shore Community College	39
Holyoke Community College	28
Cape Cod Community College	26
Berkshire Community College	13
Greenfield Community College	11
Roxbury Community College	3
% of total awards statewide	***8.2%***
Total awards, public higher education institutions	***3556***
% of total awards statewide	***26.9%***

Source: National Center for Education Statistics, Integrated Postsecondary Educational Data System

Public institutions awarded the majority of associate's degrees and certificates below the bachelor's degree level, while private institutions were responsible for the majority of degrees awarded at the bachelors, graduate, professional and graduate levels, as shown in Table 19.

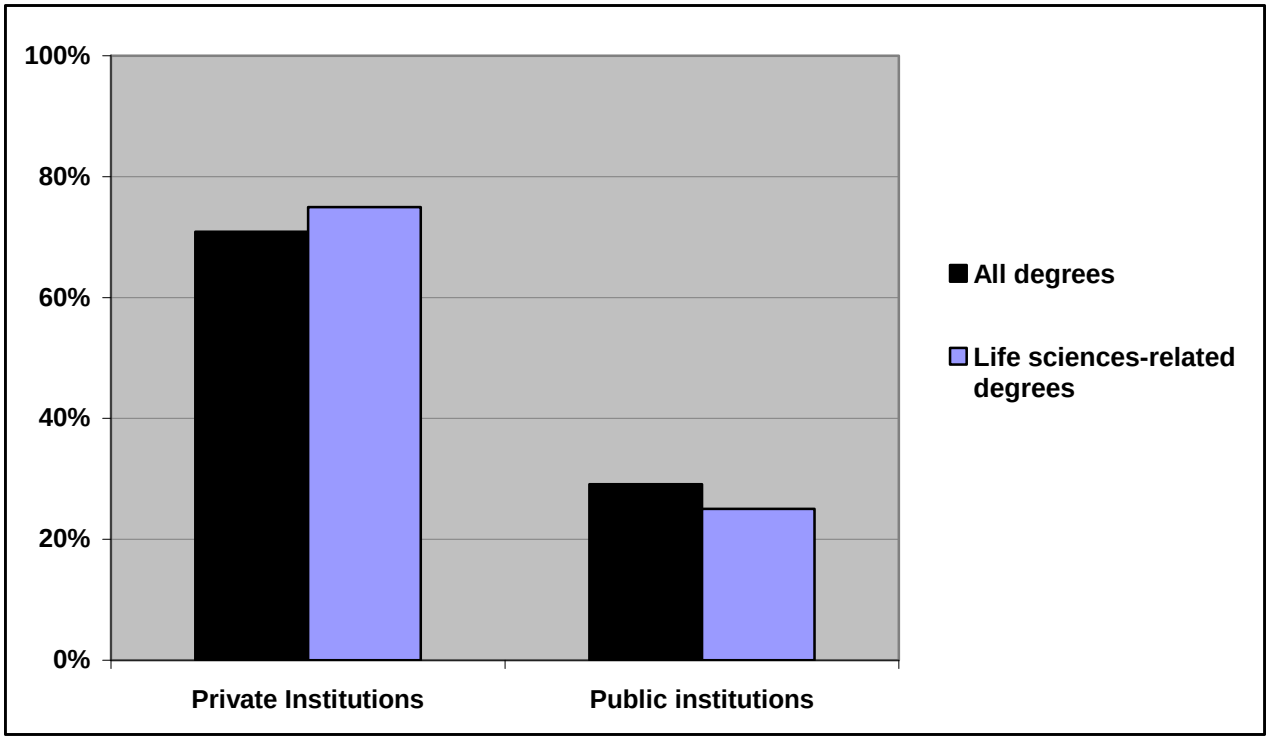
Table 19: Post-secondary degrees and certificates awarded in life sciences-related fields by level and type of institution in Massachusetts, 2006

Award Level	Sum of Total Awards	% public institutions	% private institutions
Certificates below the baccalaureate total	363	95.3%	4.7%
Associate's degree	1160	65.8%	34.2%
Bachelor's degree	7130	24.4%	75.6%
Certificates above the baccalaureate total	42	2.4%	97.6%
First-professional degree	464	0.0%	100.0%
Master's degree	2910	18.7%	81.3%
Doctor's degree	1157	14.1%	85.9%
Total Awards	***13226***	***26.9%***	***73.1%***

Source: National Center for Education Statistics, Integrated Postsecondary Educational Data System

The percentage of life sciences degrees awarded by public institutions in 2006 was smaller than the percentage of all degrees awarded by public institutions 2006, as shown in Figure 12.

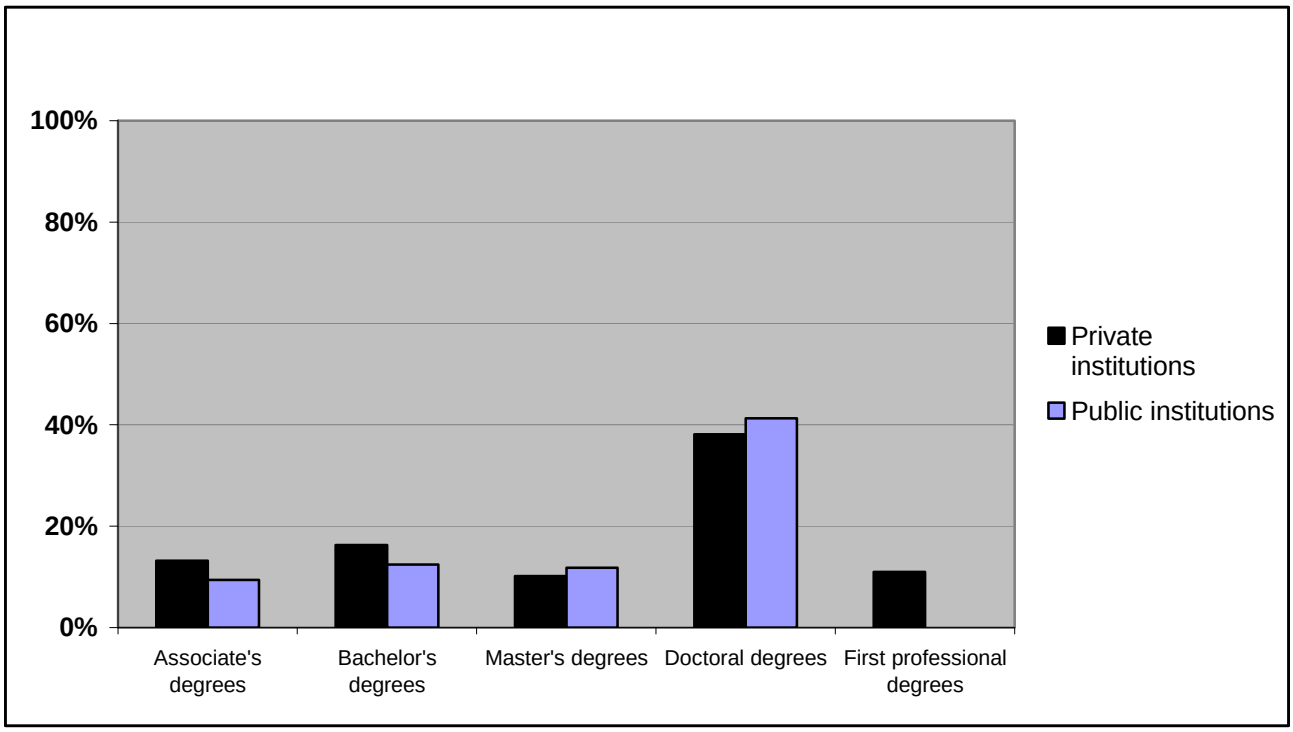
Figure 12: Degrees awarded by Massachusetts institutions, 2006



Source: National Center for Education Statistics, Integrated Postsecondary Educational Data System

Life sciences-related degrees constituted a higher percentage of all degrees awarded at the master's and doctoral degree levels in public institutions than in private institutions in 2006, as shown in Figure 13.

Figure 13: Life sciences-related degrees as a percentage of all degrees awarded by Massachusetts institutions, 2006



Source: National Center for Education Statistics, Integrated Postsecondary Educational Data System

Graduating Student Pipeline

It is difficult to assess adequacy of the pipeline of Massachusetts students and workers educated and trained to enter the life science industry. While there are data on the number of students receiving degrees and certificates in life sciences fields from Massachusetts higher education institutions, information on the post-graduation career plans of these students is for the most part not available. It is also not possible to determine how many of these students have the appropriate qualifications to meet the current needs of life sciences employers. At best, student pipeline data can provide a snapshot of the current pool of Massachusetts graduates with education in life sciences-related fields.

Graduates with doctoral degrees

Table 20 shows the number of doctoral degrees awarded by Massachusetts higher education institutions for selected life sciences fields in 2006.

Nearly 42 percent of the 1,157 new PhDs in life sciences-related fields in 2006 were foreign students. This percentage, while high, is still lower than the percentage of doctorates in the same fields awarded to foreign students in the United States as a whole (47 percent). Foreign students received more than half of the doctorates awarded by Massachusetts institutions in most of the engineering fields relevant to life sciences in 2006.

The percentage of foreign students receiving doctorates in life sciences-related fields was significantly higher for the University of Massachusetts, where 52.8 percent of new PhDs were non-U.S. resident aliens.

Table 20: Doctoral degrees awarded by Massachusetts universities in life sciences-related fields of study, 2006

Field of Study	Total Awards	% Foreign Students
Chemistry	163	42.9%
Physics	115	52.2%
Electrical, Electronics and Communications Engineering	92	46.7%
Computer and information sciences and support services.	90	51.1%
Cell/Cellular Biology and Anatomical Sciences	86	23.3%
Biology, General	73	19.2%
Biochemistry, Biophysics and Molecular Biology	71	31.0%
Mechanical Engineering	69	63.8%
Mathematics and statistics.	61	52.5%
Chemical Engineering	52	42.3%
Physiology, Pathology and Related Sciences	34	23.5%
Biomedical/Medical Engineering	33	39.4%
Microbiological Sciences and Immunology	31	12.9%
Materials Engineering	28	67.9%
Ecology, Evolution, Systematics and Population Biology	22	13.6%
Neuroscience	22	31.8%
Biomathematics and Bioinformatics	21	9.5%
Engineering Science	15	40.0%
Computer Engineering, General	14	78.6%
Pharmacy, Pharmaceutical Sciences, and Administration	12	66.7%
Operations Research	11	36.4%
Systems Engineering	7	85.7%
Engineering, Other	6	33.3%
Polymer/Plastics Engineering	6	100.0%
Manufacturing Engineering	5	100.0%
Pharmacology and Toxicology	4	25.0%
Medical Clinical Sciences/Graduate Medical Studies	3	66.7%
Biological and Biomedical Sciences, Other	2	50.0%
Botany/Plant Biology	2	50.0%
Genetics	2	50.0%
Industrial Engineering	2	50.0%
Electromechanical Instrumentation and Maintenance Technologies/Technicians	1	100.0%
Engineering, General	1	0.0%
Zoology/Animal Biology	1	0.0%
Grand Total	***1157***	***41.9%***

Source: National Center for Education Statistics, Integrated Postsecondary Educational Data System

Master's degree and first professional degree graduates

In 2006, 3,374 students received a master's or first professional degree in life sciences-related fields from Massachusetts institutions, as shown in Table 21. More than 25 percent of these degrees went to foreign students. In public higher education institutions, more than 42 percent of master's degrees were awarded to non-U.S. residents.

Table 21: Master's and first professional degrees awarded by Massachusetts universities in life sciences-related fields of study, 2006

Field of Study	Total Awards	% Foreign Students
Computer and information sciences and support services.	772	26.7%
Pharmacy, Pharmaceutical Sciences, and Administration	432	8.1%
Electrical, Electronics and Communications Engineering	313	36.7%
Mechanical Engineering	243	30.5%
Biological and Biomedical Sciences, Other	180	3.9%
Chemistry	144	37.5%
Computer Engineering, General	136	47.8%
Mathematics and statistics.	133	35.3%
Biology, General	104	20.2%
Physics	101	32.7%
Ecology, Evolution, Systematics and Population Biology	80	5.0%
Veterinary Medicine (DVM)	76	1.3%
Engineering-Related Fields	71	26.8%
Biomathematics and Bioinformatics	68	23.5%
Chemical Engineering	64	43.8%
Engineering, Other	59	28.8%
Systems Engineering	48	29.2%
Biomedical/Medical Engineering	43	20.9%
Industrial Engineering	42	54.8%
Materials Engineering	34	29.4%
Polymer/Plastics Engineering	32	59.4%
Biochemistry, Biophysics and Molecular Biology	26	15.4%
Manufacturing Engineering	26	19.2%
Engineering Science	22	54.5%
Cell/Cellular Biology and Anatomical Sciences	21	14.3%
Biotechnology	16	12.5%
Medical Clinical Sciences/Graduate Medical Studies	13	23.1%
Microbiological Sciences and Immunology	12	0.0%
Operations Research	11	54.5%
Physiology, Pathology and Related Sciences	9	22.2%
Neuroscience	8	0.0%
Systems Science and Theory	8	12.5%
Clinical/Medical Laboratory Science and Allied Professions	7	42.9%
Electromechanical Instrumentation and Maintenance Technologies/Technicians	6	50.0%
Pharmacology and Toxicology	5	40.0%
Quality Control and Safety Technologies/Technicians	4	0.0%
Genetics	2	50.0%
Botany/Plant Biology	1	0.0%
Textile Sciences and Engineering	1	100.0%
Zoology/Animal Biology	1	0.0%
Grand Total	***3374***	***25.6%***

Source: National Center for Education Statistics, Integrated Postsecondary Educational Data System

Bachelor's degrees graduates

Biology majors accounted for nearly 23 percent of Massachusetts students graduating with a bachelor's degree in life sciences-related fields in 2006 and computer and information science majors accounted for 17 percent of the

total, as shown in Table 22. Only 6.2 percent of the 7,120 life sciences-related bachelor's degrees awarded statewide in 2006 went to foreign students and U.S students represented an overwhelming majority of the graduates in virtually every field of study at the bachelor's degree level.

Table 22: Bachelor's degrees awarded by Massachusetts colleges and universities in life sciences-related fields of study, 2006

Field of Study	Total Awards
Biology, General	1633
Computer and information sciences and support services.	1226
Mathematics and statistics.	646
Mechanical Engineering	632
Electrical, Electronics and Communications Engineering	520
Chemistry	359
Biochemistry, Biophysics and Molecular Biology	343
Physics	277
Chemical Engineering	168
Neuroscience	152
Computer Engineering, General	139
Biomedical/Medical Engineering	112
Mechanical Engineering Related Technologies/Technicians	111
Computer Engineering Technologies/Technicians	96
Engineering, General	85
Electrical Engineering Technologies/Technicians	62
Clinical/Medical Laboratory Science and Allied Professions	61
Ecology, Evolution, Systematics and Population Biology	52
Engineering, Other	49
Industrial Engineering	41
Materials Engineering	41
Microbiological Sciences and Immunology	37
Biological and Physical Sciences	32
Biological and Biomedical Sciences, Other	30
Manufacturing Engineering	29
Pharmacy, Pharmaceutical Sciences, and Administration	29
Engineering Science	28
Biotechnology	27
Industrial Production Technologies/Technicians	24
Engineering-Related Fields	15
Engineering Technology, General	14
Mathematics and Computer Science	13
Physiology, Pathology and Related Sciences	13
Polymer/Plastics Engineering	13
Pharmacology and Toxicology	9
Drafting/Design Engineering Technologies/Technicians	5
Electromechanical Instrumentation and Maintenance Technologies/Technicians	2
Engineering Physics	2
Biomathematics and Bioinformatics	1
Cell/Cellular Biology and Anatomical Sciences	1
Textile Sciences and Engineering	1
Grand Total	***7130***

Source: National Center for Education Statistics, Integrated Postsecondary Educational Data System

Associate's degree graduates

The majority of associate's degrees awarded in life sciences-related fields in Massachusetts in 2006 were in computer and information sciences and engineering technology, as shown in Table 23. Biotechnology transfer and technician programs at Massachusetts Bay, Middlesex and Springfield Technical Community Colleges and Northeastern University awarded a total of 31 associate's degrees in 2006. Less than 3 percent of associate's degrees in life sciences-related fields were awarded to foreign students.

Table 23: Associate's degrees awarded by Massachusetts colleges and universities in life sciences-related fields of study, 2006

Field of Study	Total Awards
Computer and information sciences and support services.	445
Electrical Engineering Technologies/Technicians	160
Mechanical Engineering Related Technologies/Technicians	135
Engineering Technology, General	71
Drafting/Design Engineering Technologies/Technicians	61
Computer Engineering Technologies/Technicians	53
Engineering, General	50
Engineering Technologies/Technicians, Other	49
Electromechanical Instrumentation and Maintenance Technologies/Technicians	30
Biology Technician/Biotechnology Laboratory Technician	23
Natural Sciences	21
Biology, General	13
Clinical/Medical Laboratory Science and Allied Professions	12
Biotechnology	8
Industrial Production Technologies/Technicians	5
Mathematics and statistics.	5
Physics	5
Engineering Science	4
Biological and Biomedical Sciences, Other	3
Chemistry	3
Electrical, Electronics and Communications Engineering	2
Quality Control and Safety Technologies/Technicians	2
Grand Total	***1160***

Source: National Center for Education Statistics, Integrated Postsecondary Educational Data System

Between 2003 and 2006, the number of Massachusetts graduates in biological, biomedical and clinical laboratory sciences increased nearly 18 percent. There were increases in the number of graduates in these fields at every level except in Associate's degrees. The largest increase was at the doctoral degree level, where the number of graduates grew by nearly 39 percent.[49]

In contrast, the number of Massachusetts graduates in computer science and information technology fields fell by nearly 17 percent between 2003 and 2006. The largest drop was at the two-year degree level, where the number of graduates fell by nearly 44 percent over the four-year period.[50]

[49] National Center for Education Statistics, Integrated Postsecondary Educational Data System
[50] National Center for Education Statistics, Integrated Postsecondary Educational Data System

Model Programs in Massachusetts

Based on a review of academic literature, focus groups and interviews with industry leaders in Massachusetts life sciences companies and an electronic survey of employers, the Life Sciences Talent Initiative identified characteristics of higher education and workforce training programs that are most likely to be successful in meeting the industry's need for talent.

Model programs:

- Teach science through an integrated approach, emphasizing key concepts from multiple disciplines, including biology, chemistry, engineering and physics
- Teach quantitative reasoning and require students to use computers to analyze data
- Require independent laboratory research and development of technical and record-keeping skills
- Offer opportunities for students to do applied research and solve real-life problems
- Require students to develop the ability to work in teams
- Integrate practical experience into academic training through internships and cooperative education
- Communicate the relevance, excitement and potential of careers in life sciences
- Encourage entrepreneurship
- Provide for easy transition from one level of education to another
- Allow incumbent workers to pursue continuing education
- Reflect input from the industry and understanding of employer needs

The Life Sciences Talent Initiative issued a call for nominations for model programs to members of the project Advisory Committee, Academic Task Force and Workforce panel, as well as to department heads and program directors of life sciences education programs at public higher education institutions in Massachusetts. A list of nominated programs is included in Appendix H.

The following section provides summaries of selected Massachusetts higher education and workforce training programs that reflect understanding of best practices and the needs of employers. Summaries of additional programs are available as a separate appendix to this report.

Workforce Training and Associate Degree Programs

While occupational data and employer research emphasize the importance of undergraduate and graduate degree programs in meeting the need for talent in the life sciences industry, there are also opportunities for short-term education programs that train adult workers for careers in biopharmaceutical and medical device companies and clinical research.

FUNDAMENTALS OF BIOTECH MANUFACTURING AND MEDICAL DEVICE MANAGEMENT
WORCESTER POLYTECHNIC INSTITUTE

The division of corporate and professional education at Worcester Polytechnic Institute has developed a variety of education and training programs specifically tailored to train adult workers for entry into the life sciences industry and advancement within the industry.

Fundamentals of Biotech Manufacturing is a five-week training program that provides students with practical classroom knowledge and hands-on laboratory training in a simulated cGMP environment. It is taught by industry practitioners from local biotech companies, as well as WPI academic experts, using the existing infrastructure of the WPI Bioprocessing Center located at Gateway Park. The purpose of the program is to provide the participants with the skills they will need to gain entry into the biotech industry at a manufacturing operator level. The program also provides students with a network of hiring managers from biotech companies throughout Massachusetts and New Hampshire.

Four major biotech companies partnered with WPI to develop and deliver this operator-level training program for soon-to-be displaced Polaroid workers in a condensed format. The value from this program was quickly demonstrated when 90 percent of the participants secured work in a short timeframe, many receiving their job offers before officially being displaced.

"Going through this program provided me with the comprehension of the biomanufacturing industry, as well as the confidence, to enter into interviews after so many years of employment with the same company," said Mark Knowles, currently with Genzyme.

The ***Medical Device Management Certificate*** is an 11-week program that serves as a point of entry into the Medical Device Industry for individuals changing careers and a professional development tool for experienced managers new to the industry. It introduces participants to the key medical device business areas in a practical, interactive environment. The program was the result of a partnership between WPI, MassMEDIC and practicing experts from large companies, such as Boston Scientific, to small startup firms. This range of expertise provides students with insight into the industry at various stages of company development.

129 students from more than 60 companies have participated in the MDM Certificate program since its launch in 2004. In response to demand from the industry, WPI has collaborated with employers to develop a follow-on Medical Device Emerging Leader Program.

Contact: Rachel Yamartino, Program Manager, 508-831-6222, riy@wpi.edu

To ensure that training is relevant to the needs of the industry and to maximize the probability of students securing work after completing their education, workforce training programs require very strong connections between the academic institution or organization providing training and employers. In most cases, adult workers do not have the option of attending school full-time, so programs also need to be designed to accommodate work schedules.

BOSTON TEACHING HOSPITAL MEDICAL LABORATORY TECHNICIAN INITIATIVE

The Massachusetts Department of Workforce Development listed Medical and Clinical Lab Technologists among the state's occupations with the highest vacancy rates in 2006. There is a national shortage of certified professionals in this field, which is expected to get worse as older professionals retire while demand increases. To address this shortage, Beth Israel Deaconess Medical Center, Children's Hospital Boston and New England Baptist Hospital are partnering with Bunker Hill Community College and the Boston Private Industry Council on an initiative to train current hospital employees to be Medical Laboratory Technicians.

The 2.5 year program, which enrolled its pilot class in 2007, is designed to allow employees to pursue training while supporting their families. For the first six semesters, employees take BHCC courses on site at their hospital after work. In the last 6 months of the program, employees will participate in a full-time hands-on lab practicum at their respective hospitals. During this period, employees will leave their jobs, yet the hospitals will continue to provide salary and benefits as they complete their training. All tuition, book and fee costs are paid for by employers using grant funding.

Graduates of the program will earn associate's degrees in Medical Laboratory Technology and will be eligible to sit for the American Society of Clinical Pathology's Med Lab Tech certification exam. Once certified, employees will be hired as Medical Laboratory Technicians at their respective institutions. On average, participants are expected to achieve a 20 percent salary increase. They will also be positioned to move further up the career ladder to Medical Technologist roles after 2 years on the job and the acquisition of additional course credits.

The hospitals have marketed this program to current hospital employees, selected 25 students, and are sponsoring participation. Following the implementation of the pilot class, the hospitals intend to run future cohorts.

Contact: Joanne Pokaski, Director of Workforce Development, Beth Israel Deaconess Medical Center, 617-632-9395, jpokaski@bidmc.harvard.edu

Given the educational profile of workers in the life sciences industry, it is important that workforce training programs also prepare and encourage students in short-term programs to continue their education in undergraduate and graduate degree programs. Where possible, workforce training programs should be designed so that courses count for credit towards degrees.

Workforce training programs can create effective employee recruiting networks. Directors of the Middlesex Community College Biotechnology Technician and Associate's degree programs and the Just-a-Start Biomedical Careers program emphasize that graduates of their programs stay in touch and are one of the best sources of jobs for current students.

BIOTECHNOLOGY TECHNICIAN/BIOTECHNOLOGY ASSOCIATE'S DEGREE PROGRAM
MIDDLESEX COMMUNITY COLLEGE

Middlesex Community College was the first college in Massachusetts to offer a biotechnology program. Established in 1990, the program offers certificate and associate degree options, which provide the education and hands-on training in skills required for entry-level technicians in biotechnology manufacturing, research, media preparation, validation, quality control documentation and process operations.

Students enrolled in the certificate program focus on introduction to biotechnology, biology, chemistry and mathematics, as well as skills-related courses to prepare for entering the job market. The certificate can be completed in 10 months of full-time study during the day, or 16 months of part-time study in evening courses. Credits earned toward the certificate transfer to the associate degree.

Degree students complete a program that includes the college's Core Intensives, a blend of courses that develop and cultivate skills in oral and written communication, computer literacy, creative thinking and problem solving, understanding the impact of science and technology, and exploring values, ethics and social policy. Through their course work, students develop problem-solving, team work and research skills. Associate degree students may also participate in independent research.

An industry advisory board provides ongoing input on program design and course content. Professionals from the industry teach associate degree courses such as Molecular Biology, Introduction to Biochemistry, Special Topics, and QCGMP, which enables students to learn current techniques. More than ten biotechnology companies annually provide 200-hour internships for students. Most graduates obtain jobs at companies where they complete internships.

Since 1990, 780 students have enrolled in the two biotechnology programs and 362 have graduated. Many students obtain employment in the industry while still enrolled. They then complete their certificate or degree over an extended time period by continuing to take necessary courses, which are scheduled to accommodate working students. Many graduates of the certificate program return to MCC to complete the associate degree program. Graduates have continued their education by transferring to four-year institutions including Boston University, Northeastern University, UMASS-Amherst, Boston, or Lowell. There are currently 20 Middlesex students continuing in the Boston University Biomedical and Clinical Laboratory Sciences Program. Two graduates have earned masters degrees and one has received a doctoral degree from Northeastern University.

"The certificate and associate degree programs prepare students well for entry level careers in biotechnology," says Jack Fitzmaurice, Staffing Director for Wyeth in Andover, Massachusetts. "We have hired over 40 current Wyeth employees from these programs over the last 10 years. Many of these employees have excelled at Wyeth and now hold supervisory-level positions in manufacturing."

Contact: Jessie Klein, Ph.D., Associate Dean of Mathematics and Sciences, Middlesex Community College, 781-280-3862, kleinj@middlesex.mass.edu

Bachelor's Degree Programs

Public and private colleges and universities in Massachusetts are responding to the demand for interdisciplinary life sciences education at the undergraduate level. The recommendations of the Bio 2010 report are being adopted in the curricula of individual courses as well as at the program, departmental and institutional levels.

UNDERGRADUATE LIFE SCIENCES
HARVARD UNIVERSITY

One of the most comprehensive changes in undergraduate life sciences education has been implemented at Harvard College. In 2006, the Harvard Faculty of Arts and Sciences voted to replace its biology and biological science concentrations with concentrations in chemical and physical biology; human evolutionary biology; molecular and cellular biology; organismic and evolutional biology and neurobiology. The new specializations were integrated with existing tracks in anthropology; social and cognitive neuroscience and chemistry in a "life sciences cluster." The cluster spans five academic departments: Biological Anthropology, Chemistry and Chemical Biology, Molecular and Cellular Biology, Organismic and Evolutionary Biology, and Psychology.

A two-semester course, Life Sciences 1a and 1b, is required for majors in the cluster, including pre-medical students. The sequence, which is taught collaboratively by five chemistry and biology professors, provides an integrated introduction to molecular and cellular biology, chemistry, genetics and evolutionary biology. The guiding principles of the course are:

- To offer an introductory course experience that reflects currently important and exciting questions in the life sciences.
- To present students with essential knowledge and habits of mind drawn from the life sciences.
- To teach students essential scientific knowledge and skills in the context of an integrative, question-oriented approach.
- To promote insightful research and problem-solving skills rather than just rote memorization through extensive laboratory experiences.
- To facilitate appreciation of the interdisciplinary connections between fields and to associate these connections with emerging new directions of science.
- To recognize and express the diversity of intellectual and methodological approaches in the life sciences.

The introductory classes are open to all students and do not have prerequisites. First-year students expressing interest in the life sciences are asked to take placement exams in biology and chemistry for advising purposes. To accommodate students with different levels of preparation, Life Sciences 1a and 1b offer teaching assistants, weekly reviews and facilitated student study groups. In addition, a new advising structure was created for the life sciences cluster, including four life sciences cluster advisors and head tutors in each of the eight individual concentrations.

According to the Harvard Faculty of Arts & Sciences, creation of the new cluster and Life Sciences 1a and 1b represent "a first step in the revision of the entire curriculum in the Life Sciences." Plans for the future include the development of intermediate and upper-level courses based on an increased level of student sophistication emerging from the introductory courses, and opportunities for all students in the life sciences concentrations to conduct independent research with faculty members.

Contact for more information: Dr. Robert Lue, Director of Life Sciences Education, Robert_Lue@harvard.edu

Sources: www.lifescience.fas.harvard.edu; Harvard Magazine.

INTEGRATED LABORATORY SCIENCE FOR UNDERGRADATES
UNIVERSITY OF MASSACHUSETTS AMHERST

Following recommendations of the Bio 2010 report, UMass Amherst initiated a program to train biological science students for success in the interdisciplinary research environments of the future by integrating principles of physics, chemistry, mathematics, and bioinformatics into the biology curriculum. The University designed four new integrated introductory lab courses taught by teams of instructors from biology and the physical sciences. The sophomore/junior level courses, "Gene and Genome Analysis" and "Bioimaging" and freshman level "Quantitative Biology of the Cell" and "Quantitative Systems Biology" engage teams of students in open-ended projects while melding quantitative and physical science concepts and methodologies with those of biology. To date, only "Gene and Genome Analysis" has been offered; other courses will be piloted over the next three semesters. The effort is supported by the Howard Hughes Medical Institute.

The goal of "Gene and Genome Analysis" is to make students familiar with underlying principles as well as practical uses of technologies in modern molecular genetics early in their academic careers. This course provides an introduction to the increasingly important use of bioinformatics tools. Students are presented with a DNA sequence from *Arabidopsis thaliana* without any additional information. The genes chosen are true unknowns that have not been examined formally by any investigators.

During the course of the semester, the students learn all wet lab and computer techniques in the context of studying their unknown gene. They begin by preparing genomic DNA from *Arabidopsis* that they use throughout the rest of the semester as a control template in PCR reactions. After using basic bioinformatics software to develop a working gene model, they design and test primers that amplify their gene. The students then begin a phase in which computer work predominates. They use alignment tools to identify sequence-indexed T-DNA insertion mutations within their genes. Students 'order' the relevant M3 families, plant the seeds, and plan experiments that allow them to identify the genotype of each individual plant. While waiting for the plants to become large enough to genotype, they use a variety of alignment tools to discover similar genes in other species, and to discover any conserved domains that their genes possess. At this point, the students make their first formal oral presentation of a hypothesis for their gene function, and propose phenotypes that their mutant plants might show. They then turn to an examination of gene expression by mining publicly available microarray data. Some basic statistical analysis is introduced at this time. The students genotype their plants and identify the homozygous mutant individuals, and determine whether any phenotypes correlate with the mutant genotype. They devise RT-PCR experiments in which they prepare appropriate plant material. The course culminates with a formal presentation of all the data collected during the semester, including expression analysis, and the phenotypes of the mutant plants. Throughout the course, the emphasis is on the process of discovery and the number of techniques is small; preparation of nucleic acids, agarose gel electrophoresis, and PCR are the only wet lab techniques used. This allows students to focus on their research questions rather than on learning techniques, because they quickly become technically proficient and perform techniques easily and successfully by the second half of the semester. Thus, the course environment of 'Gene and Genome Analysis' supports students as they gain experience in conducting authentic scientific investigation and behave as scientists making discoveries.

The first class of students rated 'Gene and Genome Analysis' very highly. On a 5 point scale, students rated the course 4.71 overall, with scores of 4.82 for "inspired interest in the subject," 4.88 for "stimulated student participation," and 4.76 for "how much do you feel you've learned." In response to open-ended questions, students reported: "most useful and enjoyable course I've taken at UMass," "I really liked the independence because it felt like we were doing real research" and "I was able to do all the stuff I have learned about."

Contact for more information: Elizabeth Connor, Associate Professor, University of Massachusetts Amherst, 413-545-4855, econnor@bio.umass.edu

The Bio 2010 report recommended that all undergraduates studying biological science be encouraged to conduct independent research early in their studies. Developing a campus culture and systems that support student research are important elements of establishing an expectation that independent study is expected of undergraduate science majors.

OFFICE OF UNDERGRADUATE RESEARCH AND ADRIAN TINSLEY PROGRAM
BRIDGEWATER STATE COLLEGE

The Office of Undergraduate Research (OUR) is dedicated to supporting and expanding the role of undergraduate research at Bridgewater State College. Through the various funding sources on campus, and, in particular, The Adrian Tinsley Program (ATP), the OUR and its staff makes mentored research and creative opportunities available to any student with interest in a project and the commitment to see it through.

The academic culture at BSC has moved toward highlighting and conducting research opportunities for undergraduates. This shift in attitude has been lead by the science faculty, particularly in Biology and Chemistry. The ATP program allows students to apply for semester grants ($250) and summer grants ($3,200) that train students in the process of grant applications, helps them ask and define good scientific questions, and provides them with modest funds to support their research efforts. The students are mentored by faculty conducting research within that professor's area of expertise. The ATP and OUR programs have had a significant impact on students. Many of the Biology and Chemistry majors who have participated in this program have matriculated into graduate and professional programs. Since summer 2003, 70 biology and 22 chemistry majors have participated in this program, representing approximately 79 percent of department majors.

Contact: Lee Torda, Director, Bridgewater State College, 508-531-2303, ltorda@bridgew.edu

In addition to independent research, industry internships are instrumental in getting undergraduates interested in life science careers. Extended work experiences provide students with skills that make them immediately productive in the workplace following graduation. The most successful internship programs prepare students for their work experience and provide support during and after employment. To ensure that all students have the opportunity to participate, it is important that internships offer competitive compensation.

COOPERATIVE EDUCATION PROGRAM
NORTHEASTERN UNIVERSITY COLLEGE OF ARTS AND SCIENCES

Cooperative Education (Co-op) is a distinctive form of experiential education in which students alternate periods of academic study with periods of paid full-time work experiences. The learning model for the Northeastern University Cooperative Education Program includes three key elements:

1) A preparation class to help students understand employer expectations and develop skills for success in their co-op positions
2) Up to three job placements of 6 months full-time work each
3) Reflection (guiding students to identify and reflect upon what they have accomplished and learned, how these experiences connect to undergraduate studies, and how the experience has added to their intellectual growth).

Students are paid by their employer during cooperative education placements. They do not pay tuition while working but retain campus housing and student health insurance.

Undergraduate life science majors (biology, biomedical physics, biochemistry, chemistry, and behavioral neurosciences) who participate in the co-op program have opportunities to work at the cutting edge of research at prestigious teaching hospitals such as Massachusetts General and Brigham and Women's, and in biotechnology companies including Millennium Pharmaceuticals, Biogen IDEC, and Genzyme. During 2007, more than 300 NU undergraduates in life sciences were employed by organizations, both private and public, in the greater Boston community.

For the student, the co-op experience is a critical part of learning how classroom experiences may be applied to work experiences and to shaping potential career choices. Furthermore, students, as employees, often perform critical roles in the projects in which they are involved and are listed as co-authors in papers published in peer-reviewed scientific journals.

For employers, opportunities exist to recruit talented and committed students who are motivated by the challenges presented and who will make positive contributions in the near term, while building potential long-term relationships that may lead to full-time employment after graduation. In addition, employers act as mentors for future colleagues as students prepare for graduate school and careers in science and medicine.

In focus groups conducted for the Life Sciences Talent Initiative, human resource professional in life sciences companies reported that Northeastern University "co-ops" were some of their most valuable hires.

Contact: Veronica L. Porter, PhD, Faculty Coordinator, Northeastern University, 617-373-3471, v.porter@neu.edu

Graduate and Professional Degree Programs

New graduate programs are addressing the need for professionals with highly specialized training and education that crosses disciplinary boundaries. In some cases, graduate programs have evolved to allow students to explore new fields, or integrate scientific expertise with training in business, management and law. Other programs respond to a very specific need, such as veterinarians trained to care for laboratory animals.

The Integrative Graduate Education and Research Traineeship (IGERT) is a National Science Foundation program designed educate PhD scientists, engineers, and educators with the "interdisciplinary backgrounds, deep knowledge in chosen disciplines, and technical, professional, and personal skills to become in their own careers the leaders and creative agents for change." The program funds interdisciplinary graduate education and training programs and is also intended to increase participation of women and minorities in scientific fields.[51]

There are at least five Massachusetts institutions offering IGERT training programs relevant to careers in life sciences, including:

- Boston University IGERT in *Advanced Computation in Engineering and Science* and *Bioinformatics*
- Brandeis University IGERT in the *Time, Space and Structure, Physics and Chemistry of Biological Systems*
- Harvard University IGERT in *Biomechanics*
- Northeastern University IGERT in *Nanomedicine Science and Technology*
- University of Massachusetts Amherst IGERT in *Cellular Engineering* and *Nanoscale Device Development.*

Students accepted into an IGERT program may receive a $30,000 annual stipend plus additional support for tuition, fees, research equipment and supplies. IGERT programs may also offer student networking opportunities, research assistantships and industry internships. General information about IGERT programs is available through the IGERT National Recruitment Program at http://www.igert.org/index.asp

At the master's degree level, Massachusetts institutions have been slow to adopt programs based on the Professional Science Master's model. There are currently only four PSM programs in the Commonwealth, including programs in Biotechnology and Bioinformatics at Northeastern University, and programs in Industrial and Financial Mathematics at Worcester Polytechnic Institute.

The Northeastern University Biotechnology Program is in its fifth year. According to program staff, the majority of full-time students in the program are from India. Foreign students are attracted to the program because it includes a paid industry internship, offering the kind of work experience it is difficult to get at home. Domestic students in the program—accounting for about half of total enrollment—are typically incumbent workers in the industry earning their master's degree on a part-time basis.

The Harvard-MIT Health Sciences Program offers a variety of graduate degree and training programs and post-graduate courses of study integrating science, technology, engineering, informatics and business skills. Several of theses programs provide training in specialty fields that are in high demand in Massachusetts life sciences companies. Examples include a two-year program with an optional master's degree to train physicians as clinical investigators, offered in conjunction with Beth Israel Deaconess Hospital and Pfizer, and a training program in biomedical informatics, offering several degree and non-degree options in cooperation with local teaching hospitals.

[51] National Science Foundation website, http://www.nsf.gov/crssprgm/igert/intro.jsp; accessed March 18, 2008.

HARVARD-MIT HEALTH SCIENCES BIOMEDICAL ENTERPRISE PROGRAM
HARVARD UNIVERSITY AND MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Initiated in 2002, the Biomedical Enterprise Program allows graduate students to earn a master's degree in Health Sciences and Technology from the Harvard-MIT Health Sciences and Technology (HST) Program and a master's degree in Business Administration from the MIT Sloan School of Management. The program combines world-class business and medical training with the opportunity to interact with people who are advancing the frontiers of the life sciences world. The curriculum focuses on the complex process of product development and commercialization in the health-care industry, while providing students with a solid grounding in physiology, pathophysiology and issues involving patient care.

Students in the program earn a MBA at the MIT Sloan School of Management. They take biomedical sciences courses with HST MD and PhD students, focusing on learning medical terminology, physiology, and pathophysiology. Students learn the process and culture of health care through hands-on work with both patients and health care institutions. They become immersed in the unique challenges that face biomedical enterprises through courses that bring science and business together. All students complete a thesis describing original research.

A key emphasis of BEP programming is to promote networking across disciplines. Every day, BEP students interact with a community of entrepreneurs, scientists and physicians. To ensure that each student gains as much as possible from their formal and informal exchanges during the program, the BEP program sponsors a mentoring program that pairs each student with a member of the BEP Advisory Board. The Board consists of life sciences industry leaders who dedicate their time to advising students and helping to foster their ideas.

The BEP program has three tracks:

- 3-year MS/MBA program for rising business leaders
- 2-year MS/MBA Sloan Fellows program for seasoned professionals
- 1-year post-MBA MS program for trained executives

***Contact*:** Traci Anderson, Academic Programs Administrator, Harvard-MIT Health Sciences and Technology, 617-253-7470, tanderso@mit.edu

LABORATORY ANIMAL MEDICINE PROGRAM:
TUFTS UNIVERSITY CUMMINGS SCHOOL OF VETERINARY MEDICINE

Preclinical research using laboratory animals is an important component of the life sciences industry in Massachusetts. The combined degree program in laboratory animal medicine at Tufts University, established in 2004, was designed to provide the state's biomedical research community with skilled laboratory animal veterinarians with clinical and management skills to design and implement pre-clinical trials for new drug candidates and biologics, and to provide guidance in laboratory anima/l care and management of research animal facilities. Students earn both a MS in Laboratory Animal Medicine and a DVM in four years.

MS-level laboratory animal medicine courses include regulatory oversight of animal use in research, advanced training in biostatistics, ethical use of animals, comparative medicine and pathology, research animal facility administration, colony preventive medicine programs, surgical procedures, and anesthesiology of research animal species. Students are taught through lectures, small group tutorials, group projects and hands-on laboratories. Instruction is delivered through collaboration among Tufts faculty and laboratory animal veterinarians at local life science industries and academic research centers, such as Wyeth Laboratories, Genzyme, UMass Medical Center, New England Primate Research Center, and Charles River Laboratories.

To successfully complete the program, students are required to complete one summer of practical veterinary work experience at a laboratory animal facility and one summer of research experience involving animals. During the fourth year of DVM training, when students engage in practical clinical training, lab animal medicine program students spend nine weeks at approved laboratory animal facilities, both academic and in private industry.

The combined degree program encourages veterinary students to consider careers in laboratory animal medicine. Graduates are qualified for entry level positions in the field of laboratory animal medicine at biotechnology and pharmaceutical companies and academic research centers. They have expertise in animal care, experimental design, animal resource management, refinement of animal models, and independent research. They are also highly qualified candidates for laboratory animal residency programs and future ACLAM board certification.

According to Tufts, this program is unique. No other veterinary school has developed a graduate level clinical laboratory animal medicine training program that prepares students for board certification in laboratory animal medicine, other than formal residency programs that are 3-4 years in length post-DVM.

Contact: Dr. Angie Warner, Associate Dean for Academic Affairs, Cummings School of Veterinary Medicine, 508-887-4200, angie.warner@tufts.edu

Career Development Programs

Career counseling, mentoring and support are important elements of increasing the pipeline of students entering life sciences fields. While high school and college students are aware of careers in direct health care, they are typically less informed about opportunities in life science research, or of the variety of non-scientific jobs available in the industry. Career development programs play a particularly important role in encouraging students from groups that are underrepresented in the sciences, including African-Americans, Latinos, Native Americans and women, to consider opportunities offered by employment in biomedical research, development and commercialization.

There are a number of programs that identify and support young women and people of color entering life science fields in Massachusetts. CityLab Academy at Boston University is a two-semester degree-track training program that helps economically and academically disadvantaged young people obtain entry-level jobs in biotechnology and biomedical research and continue their education to advance in the field. Students in the program are mentored by BU School of Medicine graduate students.

The University of Massachusetts Medical School Summer Enrichment Program is a tuition-free four-week residential program to encourage Massachusetts undergraduate sophomores and juniors from disadvantaged backgrounds and under-represented groups to enter the health science professions. Program activities help participants improve their qualifications and competitive standing for admission to professional, graduate and/or medical school.

BIOMEDICAL SCIENCE CAREERS PROGRAM

The Biomedical Science Careers Program was founded in 1991 by the Massachusetts Medical Society, the Harvard Medical School Minority Faculty Development program and the New England Board of Higher Education, and was incorporated as a not-for-profit organization in 1994. BSCP's principal objectives are to identify, inform, support and provide mentoring to academically outstanding students and fellows from middle school to postdoctoral level, particularly African-American, Hispanic and Native American/Alaska Native students. BSCP activities aim to increase representation of minorities in the biomedical sciences and other science-related fields while helping health care institutions, biotechnology firms, educational institutions, professional organizations, and private industry members meet their need for a diverse workforce.

BSCP programs to assist students/fellows at different levels in their academic career include:

- *Biennial Student Conference* with over 700 attendees and 200 advisors designed for students from high school to postdoctoral level addresses the need for mentoring, guidance, support, and career development.

- *Skills Development Program* sessions provide approximately 250 high school and college students and 100 parents with information and guidance in areas such as the application process for college and medical/graduate/professional schools, interviewing skills, time management, study skills, conflict management, and financial planning.

- *Career Development Series* conferences provide networking opportunities, skills enhancement, and tools for career advancement for 50 to 150 physicians in postdoctoral training, junior faculty, and fellows (research and clinical).

- *Expanding Horizons* seminars and conferences focus on emerging and expanding areas of employment related to biomedical sciences.

- *New England Science Symposium* for over 180 postdoctoral fellows; medical, dental, and graduate students; post-baccalaureates; college and community college students to present their research projects through oral or poster presentations.

- *In Touch With BSCP* newsletter focusing on mentoring, financial, and career opportunities is distributed to over 7,000 students, student advisors, teachers, guidance counselors, administrators, and community organizers.

- *New England Resource Directory* provides information to students, advisors, and administrators about outreach efforts, internships, and science-related programs at New England institutions, hospitals, biomedical, and biotechnology organizations.

- *Hope Scholarships* of $7,500 to BSCP high school, community college, college, medical, and graduate students who are active in BSCP programs.

- *BSCP Linkage Program* connects BSCP students in need of advice and/or assistance with BSCP Hope Scholarship recipients.

Contact: Lise D. Kaye, Executive Director, Biomedical Science Careers Program, 617-432-0552, lise_kaye@hms.harvard.edu

Life Sciences Education and Training Strategies in Other States

A comprehensive review of state life sciences education and training programs is beyond the scope of the Life Sciences Talent Initiative. There are, however, important differences between the approach that Massachusetts has taken to preparing students and workers for the life sciences industry and strategies employed by other states.

Massachusetts colleges and universities have a well-established and well-deserved reputation for excellence in the life sciences. In general, higher education and workforce training programs in the life sciences have been conceived, developed and executed by individual institutions and organizations in Massachusetts. This approach has resulted in the creation of very strong individual programs, many of which are profiled in this report. The Commonwealth has not, however, developed a comprehensive system or strategy to coordinate these individual efforts.

Planning and coordination of programs vertically, between institutions offering programs at different levels of education, and horizontally, between different institutions offering programs at the same level, has been limited to date in Massachusetts. Cooperation between industry and educational institutions has typically occurred in the form of partnerships between a single company or an industry association and a single college or university. There has been no statewide effort to market or promote education and careers in the life sciences to high school and college students in the Commonwealth.

Other states that are seeking to strengthen their life sciences sector look to Massachusetts colleges and universities as models of excellence in life sciences education. Massachusetts can also learn from examples of other states that have developed comprehensive higher education and workforce training strategies to attract and support life sciences employers. North Carolina and California provide instructive models of coordination between higher education institutions and industry.

North Carolina

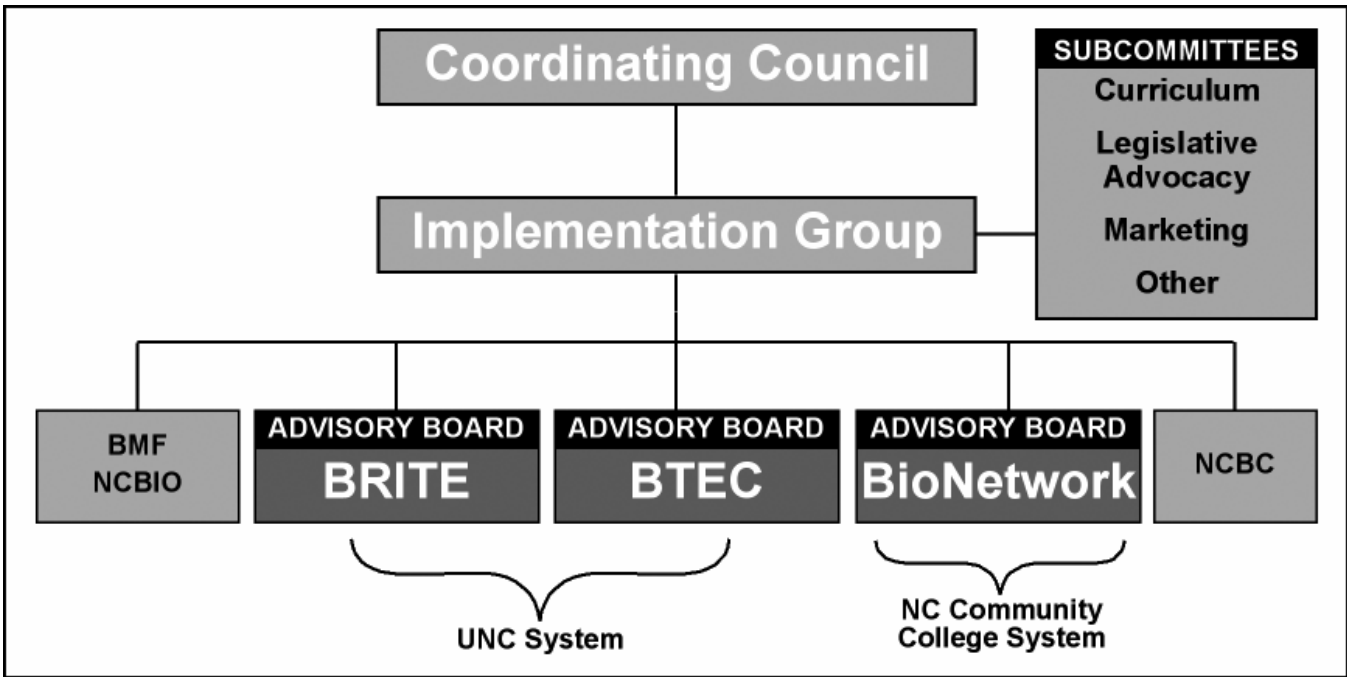
According to a 2006 Battelle Institute survey of statewide initiatives to promote the life sciences industry North Carolina has funded the nation's largest training programs in biotechnology and biomanufacturing.[52] The state has taken a system-wide approach higher education and training in the life sciences, coordinating programs between and across public institutions at the community college, state college and state university levels, and involving industry in the design of programs and public educational facilities.

Biomanufacturing and Pharmaceutical Training Consortium

As part of its investment of tobacco settlement revenue in initiatives to promote economic development, North Carolina has funded the Biomanufacturing and Pharmaceutical Training Consortium. BPTC is a collaborative effort involving industry, the North Carolina Community College System, North Carolina State University, North Carolina Central University and the University of North Carolina System in design and delivery of education and training programs to prepare North Carolina residents for employment in biomanufacturing-related industries. The goals of the consortium are to educate and train workers for highly regulated environments, enable workers to be immediately productive in complex jobs, reduce costs of new worker mistakes and educate and train workers with logical problem solving skills. BPTC encompasses education and training facilities, resources and programs on campuses across the state.[53] Figure 14 represents the structure of organizations and programs encompassed by the Consortium.

[52] Battelle Technology Partnership Practice and SSTI. *Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006.* April 2006.
[53] NC Bio website, <http://www.ncbioscience.org/forums/Biomanufacturing_and_Pharmaceutical_Training_Consortium.php>

Figure 14: North Carolina Biomanufacturing and Pharmaceutical Training Consortium structure



Source: North Carolina Biotechnology Center, 2005

Acronyms:
BMF -- Biomanufacturing Forum
NCBIO -- North Carolina Bioscience Organization
BRITE -- Biomanufacturing Research Institute and Technology Enterprise
BTEC -- Biomanufacturing Training and Education Center
NCBC -- North Carolina Biotechnology Center

BioNetwork

BioNetwork is a statewide network of North Carolina community colleges offering campus-based education and training programs for biotechnology, pharmaceutical and biologics manufacturing and related business and science curriculum. The network has developed a standard 128-hour introductory course designed for entry-level technicians in the biotechnology, pharmaceutical and chemical industries. It is currently offered at 12 of the state's 58 community college campuses, and can be customized to meet the needs of individual employers.

The BioNetwork website has information on educational opportunities and scholarships, and the project also coordinates career fairs.

BioNetwork includes several campus-based centers offering specialized resources and training to the entire system. Each center has its own advisory board encompassing representatives from industry, educational institutions and workforce training organizations. The centers include:

- The BioAgriculture Center at Robeson Community College, specializing in education and training programs to support agricultural businesses

- The BioBusiness Center at Asheville-Buncombe Community College, offering training and resources for entrepreneurs
- The BioEd Center at Gatson College, specializing in development of distance learning and web-based courses and curricula
- The Bioprocessing Center at Pitt Community College, which studies the workforce needs of manufacturers and helps community colleges develop workshops, courses and degree programs to meet these needs
- The Pharmaceutical Center at Forsyth and Guilford Community Colleges, which trains workers for the pharmaceutical industry and helps recruit new pharmaceutical business to the state
- The Validation Academy is a partnership between BioNetwork, the International Society for Pharmaceutical Engineering and the North Carolina Department of Commerce, designed to provide education and training to develop a skilled validation workforce for the state's biopharmaceutical industry.[54]

Biomanufacturing Training & Education Center

BioNetwork is also a partner in the Biomanufacturing Training & Education Center cGMP facility at the North Carolina State University Centennial Campus. The Center, which opened in September 2007, is designed to provide training on state-of-the-art equipment in a sterile manufacturing environment. It includes more than 63,000 square feet of lab space and 9,000 square feet of high-tech classrooms. Facilities include

- Bioreactors and Bioreactor control systems
- Automation with next-generation distributed control architecture
- Downstream separation and purification processes
- Aseptic processing operations
- Remote learning and data acquisition capacity on process scale equipment
- Bench-scale labs to enable learning in next-generation biomanufacturing technologies such as disposables, animal cell and tissue culture, cell therapy, protein and metabolic engineering, miniaturization and high throughput technologies and bioanalytical methodologies.[55]

Academic offerings at BTEC will include stand-alone courses, an undergraduate minor in biomanufacturing and a post-graduate certificate in biomanufacturing. A bachelor's degree program in Bioprocessing Science and a Biomanufacturing Sciences concentration in Chemical Engineering use the equipment and technical expertise at BTEC. Students and incumbent employees who enroll in programs at local community colleges will use BTEC for capstone training on industry-scale process equipment. On-campus housing is available for students enrolled in short-term courses at the facility, which is also designed to maximize capabilities for videoconferencing and distance learning.[56]

[54] BioNetwork website, <http://www.ncbionetwork.org/index.cfm>
[55] BTEC website, <http://www.engr.ncsu.edu/btec/facilities_equipment.html>
[56] BTEC website, <http://www.engr.ncsu.edu/btec/programs.html>

The BTEC Advisory Board is structured to ensure collaboration between North Carolina State University and the BTEC stakeholders, and to provide input and support for BTEC initiatives. It includes the Center's leadership, faculty and administrators from North Carolina State University, as well representatives from industry, the North Carolina Biotechnology Center, BioNetwork, state government and the Biomanufacturing Research Institute and Training Enterprise (BRITE).[57]

Biomanufacturing Research Institute and Training Enterprise

BRITE is a 52,000 square foot biotechnology and biomanufacturing research and teaching facility at North Carolina Central University in Durham. Construction is scheduled to be complete in 2008. BRITE currently has 7 tenure-track faculty and 4 staff, and offers bachelor's and master's degrees in pharmaceutical sciences.[58]

The Biomanufacturing and Pharmaceutical Training Consortium established an industrial curriculum committee to provide guidance on the knowledge and skills required by employers. In 2005, the committee produced a report on preparation for careers in the biopharmaceutical industry. The report analyzed the structure of employment in the industry in North Carolina. Based on this analysis, researchers drafted detailed job descriptions for six positions representative of the spectrum of employment in the state, including:

- Process Technician
- Process Engineer
- Process Development Associate/ Scientist
- Quality Control Assistant/Associate
- Quality Assurance Associate
- Maintenance and/or Instrumentation Technician

Researchers convened industry focus groups to review job descriptions and develop consensus on academic, technical, practical, industry-specific and interpersonal knowledge, skills, attributes and experience required for each position. This position specific information was then used to provide guidance on curriculum development. The report, published by the North Carolina Biotechnology Center, is intended as a "living document" that will be continuously updated based on feedback from employers.[59]

North Carolina Biotechnology Center

The state-funded North Carolina Biotechnology Center (NCBC) promotes life sciences careers to elementary, high school and college students. In 2006, the center commissioned a career marketing publication from the North Carolina Department of Public Instruction. *Career Pathways: Focus on Biotechnology* is a full color 25-page overview of opportunities in the industry targeted to high school students, parents and educators. It emphasizes the social value created by the industry, and provides information on job roles and responsibilities, education and training requirements and salaries for a variety of positions, from research scientists to instrument maintenance technicians.[60]

NCBC also offers Education Enhancement Grants to support biotechnology education from grades K to 16+. Grants of up to $100,000 are available to all non-profit institutions for equipment purchases and curriculum development.[61]

[57] BTEC website, <http://www.engr.ncsu.edu/btec/advisory.html>
[58] BRITE website, <http://brite.nccu.edu/?q=node/2>
[59] North Carolina Biotechnology Center, 2005.
[60] North Carolina Department of Public Instruction, 2006, link accessible from NCBC website <http://www.ncpublicschools.org/cte/publications/career_pathways/biotechnology_career_publication.pdf>
[61] NCBC website, <http://www.ncbiotech.org/resource_center/for_educators/documents/ETInfoSheet-02-08Update-w.pdf>

California

California has also been proactive in developing comprehensive life sciences education and training facilities and programs that are coordinated across public higher education institutions, including community colleges, state colleges and the University of California system.

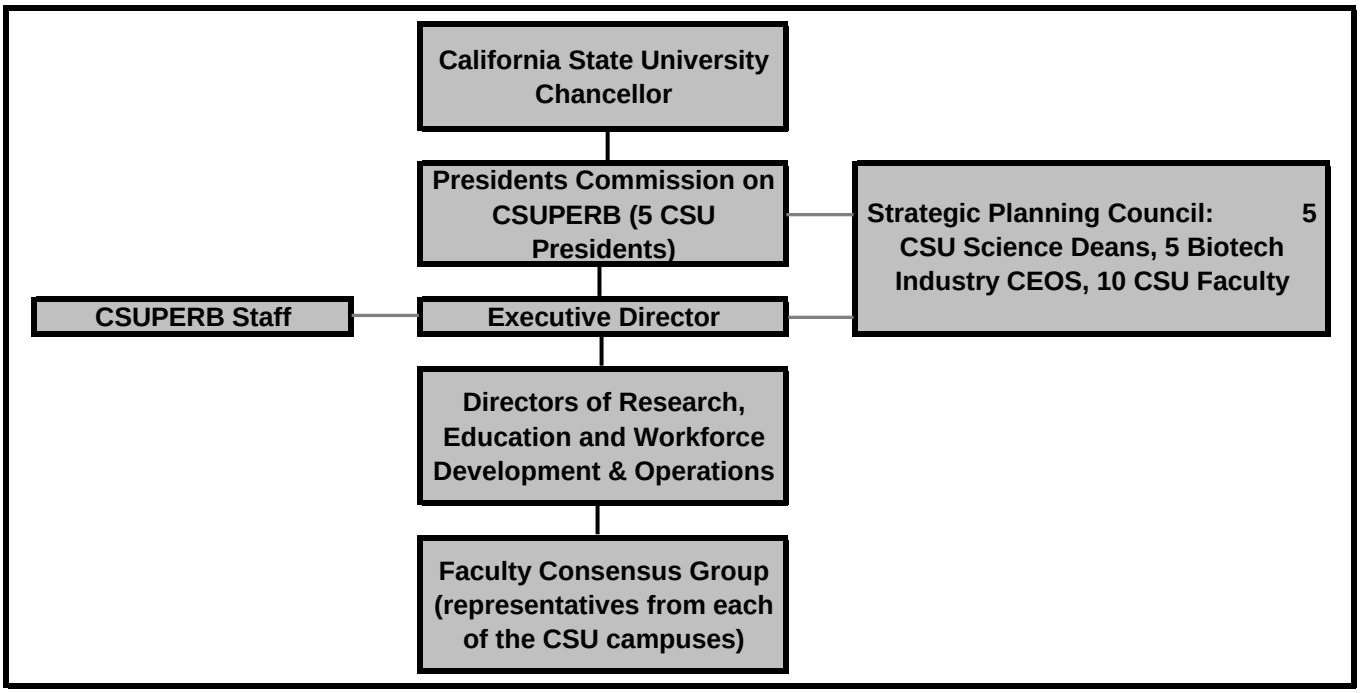
California Community College Biological Technologies Initiative

The California Community College Biological Technologies Initiative is a statewide coordinating program for biotechnology career education at the community college level. CCBTI has a state office and director as well as six regional centers on campuses across the state. Each center has its own director and advisory board; regional center representatives are included in a statewide advisory committee that meets several times a year. CCBTI's website provides links to the regional centers and to more than 50 community colleges offering courses or degree programs in biotechnology across the state. In 2006, CCBTI published a report on industry skill and training needs and how the community college system could respond.[62]

California State University Program for Education and Research in Biotechnology

At the state college level, the California State University Program for Education and Research in Biotechnology was established in 1987 to provide "vision, leadership, and support for biotechnology education and research" across the CSU system to promote biotechnology in California. Like CCBTI, CSUPERB is a multi-campus program with a central office and director. It serves as the official liaison between the CSU and industry, state government and the public on issues related to biotechnology.[63]

Figure 15: CSUPERB management structure



Source: CSUPERB website, <http://www.csuchico.edu/csuperb/ManageChart.htm>

[62] California Community College Biological Technologies Initiative website, <http://www.cccbiotech.org/>
[63] CSUPERB website, <http://www.csuchico.edu/csuperb>

CSUPERB's website lists biotechnology-related academic programs in the CSU system by topic, region and campus. An annual CSUPERB symposium provides students and faculty in the CSU system with an opportunity to present their research.

CSUPERB has developed "core facilities" that provide specialized instruments, staff and laboratories at host campuses. Each facility focuses on a different technology, and all centers serve both research and education functions. Current core facilities include:

- Microchemical Core Facility DNA Lab at San Diego State University
- Confocal Microscope Core Facility at CSU Stanislaus
- W.M. Keck Foundation Center for Molecular Structure/X-Ray Crystallography at CSU Fullerton
- Micro-Chemical Elemental Analysis Facility at CSU Long Beach

CSUPERB has established goals for the core facilities. Each facility is required to:

- Serve and maintain a broad academic constituency, either regionally or statewide;
- Continually seek external funding to update and upgrade instrumentation to keep up with technological advances in the field;
- Develop strategies or technologies that will foster collaboration in research and curricular development and allow increased access of the facilities to CSU students, faculty, and staff;
- Provide regularly scheduled workshops, individual training sessions, and other pertinent training activities;
- Show evidence of the publication of findings and accomplishments that were derived from the research and service activity, and acknowledgment of the participation and commitment of CSUPERB to the core facility.[64]

CSUPERB awards start-up funding for new core facilities to campuses on a competitive basis. Applications for start-up funds must demonstrate the proposed new facility 1) offers unique research and educational capabilities to the CSU system 2) provides clear cost advantages over existing available facilities; and 3) will have a critical mass of users that include faculty, staff and/or students at CSU campuses **other** than those at the host institution. Proposals must also include a strategic plan, including mission, goals, significant milestones and a list of measurable outcomes that will be used to judge the success of the facility; detailed descriptions of all the services and planned research and training activities at facility, a three-year operating budget listing sources of revenue and a detailed plan to achieve funding independence. Facilities must submit annual reports to CSUPERB documenting activities, expenditures, and progress towards measurable outcomes.[65]

In addition to providing start-up and operating support to core facilities, CSUPERB operates a variety of grant programs in the CSU system. Grants are available for development of workshops and short courses, biotechnology curriculum and infrastructure, faculty-student collaborative research projects, faculty and student travel and entrepreneurial joint ventures. Most but not all grants require matching funds.[66]

[64] CSUPERB website, <http://www.csuchico.edu/csuperb/CoreFacilityPolicy.htm>
[65] CSUPERB website, <http://www.csuchico.edu/csuperb/CoreFacilityPolicy.htm>
[66] CSUPERB website, <http://www.csuchico.edu/csuperb/Grants.htm>

California Institutes for Science and Innovation

In 2000, the University of California system entered into a partnership with the state and industry to create the California Institutions for Science and Innovation. The state made a commitment to invest $400 million in four new research institutes on UC campuses. The institutes were explicitly intended to "create a new environment for industry scientists to collaborate in fundamental research and to educate future scientists."[67] Two of the four California institutes have missions, facilities, research and programming at the cutting edge of the life sciences.

The California Institute for Quantitative Biosciences, also known as the California Institute for Bioengineering, Biotechnology, and Quantitative Biomedicine or QB3, is a collaboration between three campuses. UC San Francisco, with a specialty in medical science, is the lead campus; UC Berkeley brings strength in engineering and physical science and UC Santa Cruz provides specialization in mathematics. The goal of the institute is to integrate biological research with quantitative science. QB3 offers seminars, undergraduate internships and a graduate degree specialization in computational and genomic biology. Affiliated projects include the Center for Bioentrepreneurship at UC San Francisco and the Synthetic Biology Engineering Research Center, which is a partnership between UCSF, UC Berkeley, MIT and Harvard.[68]

The California Nanosystems Institute is predominantly a research institute. Areas of investigation include renewable energy, environmental nanotechnology and nanotoxicology; nanobiotechnology and biomaterials; nanomechanical and nanofluidic systems and nanoelectronics, photonics and architectonics. CNSI is developing a graduate degree program in nanosystems research and technology. CNSI also offers fellowship programs in nanoscience and nanotechnology available at graduate and postdoctoral levels.[69]

[67] CISI website, <http://www.ucop.edu/california-institutes/>
[68] QB3 website, <www.qb3.org>
[69] CNSI website, < http://www.cnsi.ucla.edu/>

MEETING THE NEED FOR TALENT

Occupational data analysis and employer research conducted for the Life Sciences Talent Initiative provide an overview of the current workforce strengths and emerging needs. Investigation of the structure and content of life sciences education and training programs in Massachusetts, analysis of graduating student pipeline data and review of education and training strategies in other states and nations offers insights on the strengths and weaknesses of the Commonwealth's existing talent development system. The LSTI survey asked employers to evaluate and rank strategies to meet their need for talent. All of this data were used to engage employers, educators and policy makers in a conversation about general and specific actions that industry, educational institutions and state government should take to ensure that the Massachusetts life sciences industry has the talent it needs to thrive and grow.

Employer Priorities

The LSTI survey provided a list of 15 different actions that emerged from research on potential strategies to meet the need for talent in the life sciences industry. Respondents were asked to rate the usefulness of each strategy as "high," "medium" or "low." Employer responses are summarized in Table 24.

Table 24: Employer assessment of strategies to meet the need for talent, LSTI survey

How useful would each of the following strategies be in helping your organization meet its human capital needs in Massachusetts?	% of respondents that said "highly useful"
Implement targeted programs to increase supply of workers for specific high-demand, hard-to-fill positions	56.5%
Promote life sciences careers to college students and career counselors	54.8%
Increase student internship and co-operative education programs	50.0%
Publicize current job openings in life sciences to students and recent graduates	46.8%
Increase industry input into higher education, workforce training programs, and curricula	43.5%
Promote life sciences careers to middle and high school students, parents and guidance counselors	41.9%
Increase emphasis on laboratory research and skills in higher education programs	32.3%
Increase training for workers displaced from other industries	32.3%
Increase visas for foreign workers in high demand positions	30.6%
Increase programs to improve the skills of incumbent workers	29.0%
Provide financial incentives for students trained in life sciences to stay in Massachusetts	29.0%
Provide housing assistance to recruit and retain workers in high-demand positions	27.4%
Conduct an annual human capital needs assessment of Massachusetts life sciences employers	25.8%
Increase emphasis on independent and applied research in higher education programs	25.8%
Expand English as a Second Language programs	19.4%
Answered question	***62***

The survey also asked respondents to select the five most important strategies from this list in order of priority. Results are shown in Table 25.

Table 25: Employer priorities to meet the need for talent, LSTI survey

Which of these strategies should be the highest priority for implementation? (choose up to five)	% of respondents choosing as one of five priorities	% of respondents choosing as top priority
Implement targeted programs to increase the supply of workers for specific high-demand, hard-to-fill positions	56.5%	17.7%
Increase industry input into higher education, workforce training programs, and curricula	54.8%	21.0%
Increase student internship and co-operative education programs	48.4%	8.1%
Promote life sciences careers to college students and career counselors	43.5%	4.8%
Publicize current job openings in life sciences to students and recent graduates	37.1%	12.9%
Increase emphasis on laboratory research and skills in higher education programs	35.5%	1.6%
Increase visas for foreign workers in high demand positions	30.6%	4.8%
Provide housing assistance to recruit and retain workers in high-demand positions	29.0%	4.8%
Promote life sciences careers to middle and high school students, parents and guidance counselors	29.0%	6.5%
Provide financial incentives for students trained in life sciences to stay in Massachusetts	27.4%	1.6%
Conduct an annual human capital needs assessment of Massachusetts life sciences employers	22.6%	6.5%
Increase programs to improve the skills of incumbent workers	22.6%	6.5%
Increase training for workers displaced from other industries	21.0%	1.6%
Increase emphasis on independent and applied research in higher education programs	19.4%	1.6%
Expand English as a Second Language programs	11.3%	0.0%
	answered question	***62***

Implementing targeted programs to increase the supply of workers in high-demand positions, increasing industry input into education and training programs, increasing internship opportunities and promoting life sciences careers to college students emerged as the highest priorities from the survey.

Life Sciences Talent Summit

The Life Sciences Talent Initiative convened a one-day summit of leaders in the life sciences industry, state government, higher education and workforce development at UMass Boston on February 1, 2008. The purpose of the Summit was to report and discuss results from the research and build consensus on key strategies to meet the need for talent.

The Summit included addresses by Governor Deval Patrick and Vertex Pharmaceuticals Chief Executive Officer Dr. Joshua Boger. UMass Donahue Institute staff presented findings from LSTI research, with responses by panelists from industry, higher education and workforce development. Participants broke into four working groups to discuss education and training strategies and priorities for implementation. Working group leaders summarized discussions in a plenary session, with concluding remarks from cabinet members, legislators and executives from industry and higher education. A Summit agenda and list of attendees are included in Appendix I.

Summit speakers, panelists and attendees confirmed major findings from the research. Major themes from the Summit working group discussions included the following:

Need for a collaborative life sciences higher education and training system

In a working group session about building partnerships between industry and higher education, Massachusetts Biotechnology Education Foundation Executive Director Lance Hartford observed that "North Carolina has a system for workforce development. Massachusetts has lots of programs."

In the same session, two University of Massachusetts Amherst professors expressed the need for better connections to employers. Associate Professor of Entomology John Burand said that he teaches an undergraduate biotechnology course, but added "I wonder what I am training my students for—I have no connection to industry that could inform me how to better train students, both in terms of skills and how to think creatively." Chemical Engineering Professor and Department Head TJ Mountziaris explained that connections between educators and employers, where they exist at all, are likely to have evolved through chance interactions. He described how he developed a relationship with scientists at Genzyme as a result of meeting the father of one of his students, who was employed by the company. Representatives from educational institutions emphasized that they also have the capacity to provide specific, targeted short- and medium-term training programs to meet industry needs, but they often lack information on what type of training is needed. Commonwealth Corporation Director of Research Navjeet Singh commented "It is not efficient for individual schools and professors to have to network with individual businesses—how can this be done more efficiently?"

Participants in all four working groups at the Summit concluded that Massachusetts needs to develop formal networks and systems to ensure communication between higher education administrators and faculty, workforce training organization, life sciences employers, industry associations and state government about the need for talent, and collaboration on plans and programs to meet that need.

Summit participants identified two priorities for a more systemic approach to life sciences education and training. They strongly supported plans by the MassBioEd Foundation to develop and launch a web-based clearinghouse of information on higher education and training programs for life sciences. Representatives from both industry and educational institutions also emphasized the need for an organization or network to develop more internship opportunities and place students in these positions.

Need for career information and marketing of opportunities in the life sciences industry

Lack of public information on opportunities in the life sciences industry in Massachusetts was another problem identified by Summit attendees. Participants emphasized the need for a comprehensive public outreach effort to communicate that the life sciences industry offers a variety of exciting, challenging, rewarding and financially attractive careers in both scientific and non-scientific fields. "Careers in biotechnology are varied," said Ann Stanesa of Genzyme. "Not everyone is a scientist! We have jobs in marketing, sales, technical writing, etc."

To increase the pipeline of young people entering the life sciences, Summit participants recommended that career outreach efforts begin in elementary and middle school. Suggestions included sending scientists to schools as "career ambassadors," and encouraging interest in science among young people through field trips to medical and research facilities. Outreach to parents through parent-teacher organizations, after-school programs and churches was another recommendation.

At the high school and undergraduate level, Summit participants recommended more creative and effective use of electronic media for career education and communication. It was suggested that Massachusetts investigate the feasibility of implementing an electronic career guidance and database system. The Georgia Career Information

System (<http://www.gcic.peachnet.edu/>) was cited as a potential model. Other suggestions included creative use of social networks, podcasts, U-Tube and "virtual world" sites such as Second Life to promote careers in life sciences to high school and college students.

Industry and higher education representatives also voiced the need for more effective methods of publicizing current job openings to Massachusetts residents, including centralized job databases and regional career fairs for graduating students.

Need for a more aggressive and proactive approach to seeking and developing in-state talent

Summit attendees identified a variety of sources of in-state talent that are not being maximized, including but not limited to:

- Talent in regions outside Boston, Cambridge and Worcester
- Talent in underrepresented communities statewide, including African Americans, Latinos, immigrants and first-generation college students
- Talent in populations of adult workers displaced from other industries
- Talent in manufacturing firms that are not currently engaged in production for the life sciences industry
- Talent in vocational schools

"One of the biggest assets of the Commonwealth is our size," commented one Summit participant. "The regional conversation needs to take into account that there's a lot here – curriculum, students and jobs – and we just need to make it accessible because it's so close." The need to make better connections between students graduating with life sciences degrees from colleges in western Massachusetts to opportunities in eastern Massachusetts was a common theme of the Summit, as was the potential for manufacturing firms in western Massachusetts to meet demand for products from medical device and biotechnology firms that are currently being outsourced to companies in other states and nations.

Shifting state demographics suggest a need to reach out to groups that are underrepresented in the life sciences industry. Educators recommended that industry, higher education institutions and the state commit additional resources and effort to encouraging and preparing children of immigrants, first generation college students, African American and Latino students to enter and succeed in STEM fields.

Loh-Sze Leung, Director of Skillworks, reminded Summit participants that 60 percent of the 2020 workforce is in the workforce today. "The K-12 pipeline is important, of course," she acknowledged, "but are there opportunities to provide existing workers with training to enter/transition into life sciences careers?" Biotechnology employers shared stories about successful efforts to hire workers displaced by plant closings in other industries, including chemical workers from a Polaroid plant and manufacturing employees from a sugar plant. John Sauers, training manager for Abbott Bioresearch Center in Worcester, recommended the use of a questionnaire to help companies identify good adult candidates for training programs, and to help displaced adult workers identify opportunities best suited to their skills and interests.

Several representatives from biotechnology and medical device companies expressed optimism about the future of manufacturing in Massachusetts. They warned, however, that the viability of manufacturing will depend on the availability of trained, skilled workers. Vocational schools have been a good source of manufacturing talent in the past, especially for medical device companies, and employers wanted to communicate that there are still jobs for skilled machinists and other technicians.

Existing resources

Participants in the Life Sciences Talent Summit emphasized that Massachusetts should, to the extent possible, use existing networks and resources to meet the need for talent in the life sciences industry. It was suggested that the state's workforce investment boards and industry associations could assist in improving coordination between educational institutions and employers. The Massachusetts Office of Business Development could play a role in connecting companies with new in-state suppliers. Alumni networks could be formalized and used more effectively for communication of job opportunities.

Summit attendees identified the need for an electronic clearinghouse for information on education and training programs relevant to life sciences and an electronic career advising system as priorities. There are several existing electronic resources that provide some of this information.

MassMentor

MassMentor (<www.massmentor.edu>) is an online resource sponsored by the Massachusetts Board of Higher Education and the Association of Independent Colleges and Universities in Massachusetts designed to help students and their parents plan for careers and higher education. It includes a database of information on public and private colleges and universities in Massachusetts, including programs of study offered by each school as well as information on admissions and financial aid.

The career planning section of the website includes self-assessment tolls, lists of careers by cluster, and information on individual careers including a description, typical tasks, related careers and higher education majors, and information on Massachusetts schools offering related education and training programs. Unfortunately, information is not available for some key life sciences occupations, such as biochemists and biophysicists, and the information listed for other careers is so general that it is not very useful for career planning purposes. However, this resource could be updated and adapted to reflect current information on life sciences occupations and the Massachusetts institutions that provide education and training for careers in the industry.

Biotech Work Portal

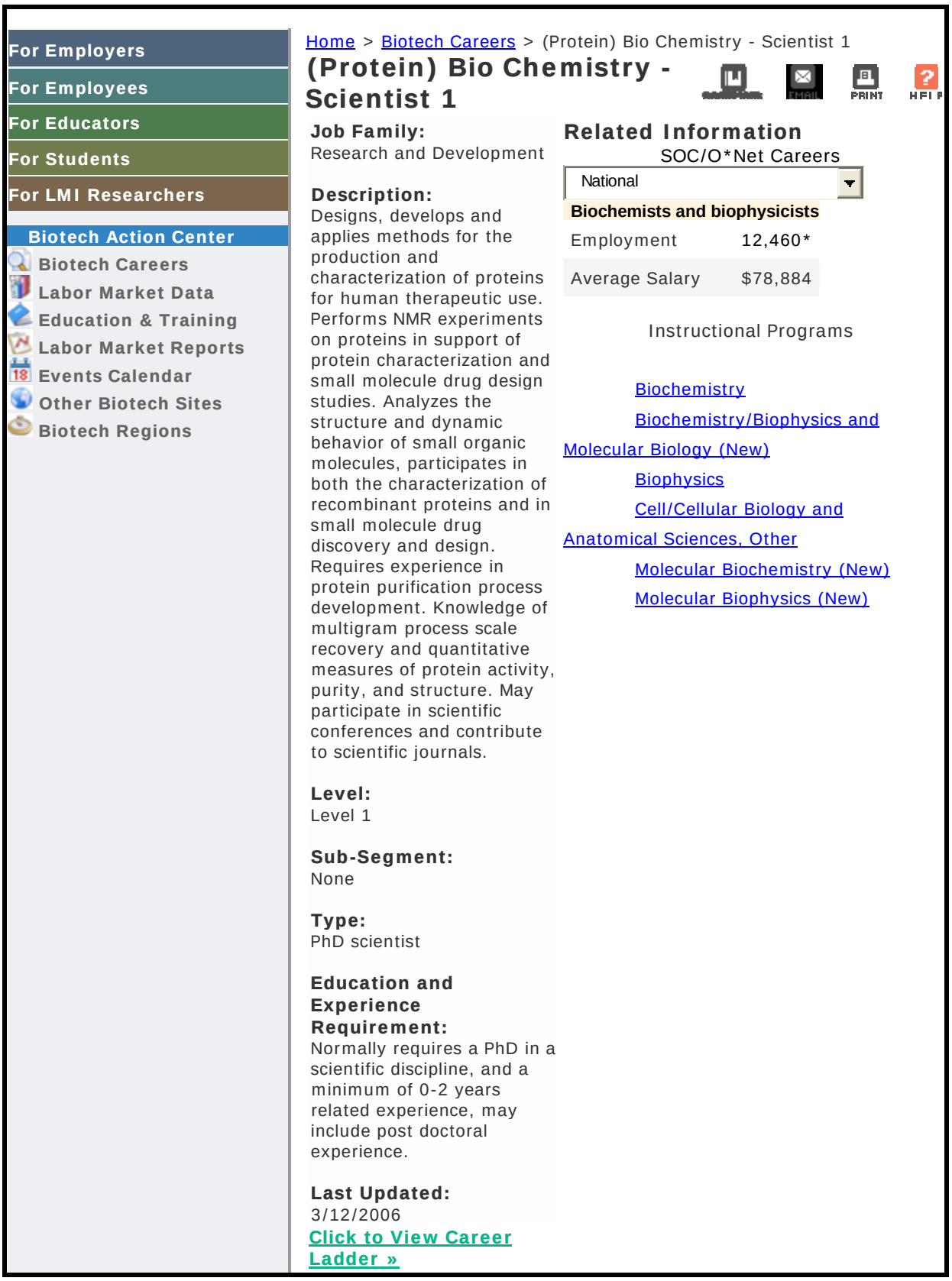
At the Bio2007 conference in Boston, the San Diego Workforce Partnership launched a new national electronic database of career, educational and labor market information on the broadly-defined biotechnology industry. The Biotech Work Portal (<www.biotechwork.org>) includes detailed information on biotechnology-related careers, higher education and training programs, labor market statistics and reports, industry events and links to other websites.

Like the MassMentor website, the Biotech Work Portal includes descriptions of occupations in the industry and information on the education and skills needed to prepare for these careers. However, the work portal uses the occupational definitions and education and experience requirements developed by Radford Surveys + Consulting based on actual industry surveys. This classification system, as described by the Sand Diego Workforce Partnership, includes both scientific and non-scientific occupations, and "encompasses 197 unique job titles, which expand to 829 job titles when all of the job levels are included…The full 829 job titles can be used to build a biotechnology career ladder with nine major strands: administration; business development/ marketing/ sales support; clinical; information systems; process development/ manufacturing/ production; quality assurance; quality control; regulatory affairs; and research and development."[70] These career ladders are graphically represented on the Biotech Work Portal website to show relationships between positions and educational and career paths for advancement. Visitors to the website can search each of the 829 job titles and find job descriptions, education and experience requirements, average national salaries and a list of fields of study that are relevant to preparation for the occupation (see figure 16, below).

The Biotech Work Portal also includes a national database of higher education and training programs in the life sciences. Website users can search for instructional programs by location, occupation, institution title or level of education. Information on educational programs was assembled using data reported by colleges and universities to the National Center for Education Statistics, so the relevance of the information depends on the accuracy of these individual reports.

[70] San Diego Workforce Partnership, 2006.

Figure 16: Section of sample career information page from Biotech Work Portal website



For Employers
For Employees
For Educators
For Students
For LMI Researchers

Biotech Action Center
Biotech Careers
Labor Market Data
Education & Training
Labor Market Reports
Events Calendar
Other Biotech Sites
Biotech Regions

Home > Biotech Careers > (Protein) Bio Chemistry - Scientist 1

(Protein) Bio Chemistry - Scientist 1

Job Family:
Research and Development

Description:
Designs, develops and applies methods for the production and characterization of proteins for human therapeutic use. Performs NMR experiments on proteins in support of protein characterization and small molecule drug design studies. Analyzes the structure and dynamic behavior of small organic molecules, participates in both the characterization of recombinant proteins and in small molecule drug discovery and design. Requires experience in protein purification process development. Knowledge of multigram process scale recovery and quantitative measures of protein activity, purity, and structure. May participate in scientific conferences and contribute to scientific journals.

Level:
Level 1

Sub-Segment:
None

Type:
PhD scientist

Education and Experience Requirement:
Normally requires a PhD in a scientific discipline, and a minimum of 0-2 years related experience, may include post doctoral experience.

Last Updated:
3/12/2006

Click to View Career Ladder »

Related Information

SOC/O*Net Careers

National

Biochemists and biophysicists

Employment	12,460*
Average Salary	$78,884

Instructional Programs

Biochemistry
Biochemistry/Biophysics and Molecular Biology (New)
Biophysics
Cell/Cellular Biology and Anatomical Sciences, Other
Molecular Biochemistry (New)
Molecular Biophysics (New)

Source: Biotech Work Portal, <www.biotechwork.org>

Bio-Link

Bio-Link is a National Advanced Technology Education Center that provides resources to improve and expand educational programs that prepare skilled technicians to work in the biotechnology industry. The Bio-Link website (<www.bio-link.org>) provides a list of biotechnology technician training programs by state, with links to program information. The Bio-Link Clearinghouse of Instructional Materials for Biotechnology Technician Education is a web-based resource of instructional and curriculum materials that are specifically targeted for courses and programs that educate biotechnology technicians and bench scientists.

The Biolink website also includes a job database and list of internship and fellowship opportunities. As of March 2008, these resources did not appear to be up-to-date.

RECOMMENDATIONS

Massachusetts has a strong foundation for producing talent to support the life sciences industry. However, the state faces challenges due to current industry dynamics — business creation and expansion; the growing importance of downstream functions; reliance on an immigrant workforce; and the lack of sufficiently strong and widespread connections between and among industry, educational institutions and workforce development organizations.

If industry's future talent needs are to be met, the state, industry, academic institutions and workforce training organizations need to move in new, more effective, and more collaborative ways than we've seen to date.

Specifically, action is needed in five areas:

Graduate and Professional Education

The Massachusetts life sciences industry is growing and requires a steady stream of professional talent in a wide range of fields, from biomedical science, engineering and product development to legal and regulatory affairs, marketing and sales, manufacturing, business management, accounting and informatics. Life sciences employers need a highly versatile professional workforce that can innovate and adapt to new discoveries and pressures generated by global competition. A bachelor's degree is required for more than 80 percent of new jobs in the industry. Many positions require additional on-the-job, graduate and post-graduate training.

Massachusetts life sciences companies have been meeting their professional talent needs through in-house training programs, by hiring experienced workers from other Massachusetts firms, and by recruiting staff from other locations. While these strategies have been successful, they are also expensive. Employers are eager to work with Massachusetts colleges and universities to produce more graduates with the education, skills and experience needed to succeed in professional positions in the industry.

Employers surveyed and interviewed for LSTI report that students who earn graduate and professional degrees from Massachusetts schools are well-prepared for jobs in the life sciences industry. To capitalize on the success of graduate and professional education in the Commonwealth and to increase the supply of professional workers with advanced degrees, LSTI offers recommendations in the following areas:

Produce and retain more graduate students with interdisciplinary training

Massachusetts colleges and universities offer a variety of existing and new graduate and professional degree programs that are specifically designed to prepare students to take advantage of professional opportunities in the life sciences industry. Examples, many of which are highlighted in this report, include:

- Integrative Graduate Education Research and Traineeship (IGERT) programs related to life sciences at Boston University, Brandeis, Harvard, Northeastern and UMass Amherst,
- Doctoral, medical and master's of science degrees offered by the Harvard-MIT Health Sciences Program,
- Professional Science Master's degree programs in Biotechnology and Bioinformatics at Northeastern University
- Master of Science degree in Health Product Regulation at Regis College

- Laboratory Animal Veterinarian degree program at Tufts University
- New Master of Science degree program in Clinical Investigation for healthcare professionals at UMass Medical School
- Intercampus UMass graduate degree program in Biotechnology and Biomedical Engineering

Some of these programs are well-connected with local employers, which serve as a fertile ground for recruiting students and adjunct faculty, as well as providers of internships and jobs for graduates. Employers and educational institutions need to build on these connections, and maintain an ongoing dialogue to ensure that curriculum stays up-to-date. To determine how well these programs are meeting the need for talent in the Massachusetts life sciences industry, it would be useful to track employment and career paths of graduates.

Other states with a strong life sciences industry sector have been more active in the development of Professional Science Master's degree programs than Massachusetts. Higher education institutions in the Commonwealth should work with industry to identify opportunities for new graduate degree programs in areas of high demand. Possibilities include programs in the following areas, all of which are offered by the Keck Graduate Institute of Applied Life Sciences in California:

- PSM program in clinical research for students without a prior degree or experience in health care
- PSM program in biomedical devices and diagnostics
- PSM program in the business of bioscience
- PSM program in biopharmaceutical discovery and development

While several Massachusetts law schools offer concentrations in health law, there are relatively limited options for specialized legal education in issues relating to biotechnology products and biomedical devices in the Commonwealth. Given the growing need for legal expertise in the Massachusetts life sciences industry, there may be opportunities for law schools to develop concentrations and joint J.D./M.S. programs in this area.

Offer targeted corporate education and certificate programs

Targeted post-baccalaureate training programs for incumbent life sciences workers and career-changing professionals may be useful in helping employers to meet short-term demand for talent in key functional areas, including clinical and regulatory affairs, project management, and marketing and sales. Industry associations are well-placed to take the lead in assessing employer demand for these programs and working with educational institutions to develop and host programs.

Offer entrepreneurial and management training in life science graduate degree programs

Participants in the Life Sciences Talent Summit observed that conventional graduate degree programs in biological and biomedical sciences, chemistry and physics often assume an academic career path, and offer students little exposure to the possibility of professional jobs in industry, or in careers that bridge the gap between research and practice. Employer outreach to these programs could help encourage graduate students to consider opportunities in industry. Possible offerings could include industry speaker series, industry internships, design competitions for graduate students, and a regional industry-sponsored entrepreneurship program for graduate students serving multiple institutions. Conventional degree programs could also encourage students to take courses in business management.

Increase financial incentives and assistance for graduate students

While financial assistance is often available for doctoral students in pure science fields, there is limited assistance available for students pursuing professional and applied degrees in life sciences. Expansion of financial incentives for Massachusetts residents to earn graduate and professional degrees in life sciences fields and work

in Commonwealth following graduation could help increase the pipeline of life sciences workers with post-baccalaureate education in high-demand specialties.

Undergraduate Education

Discussions about improving life sciences education and training at the bachelor's degree centered around two sets of issues: increasing the quantity and diversity of undergraduate science majors, and improving student preparation for a range of careers in the life sciences industry.

Increase the quantity and diversity of Massachusetts residents with bachelor's degrees in STEM fields

Implement recommendations of Readiness Project to improve pre-matriculation preparation for undergraduate science

Undergraduate faculty involved in LSTI observed that while many Massachusetts students enter college with a desire to study science, they do not have sufficient preparation in mathematics to succeed in science degree programs without substantial remedial work. A recent state study of students at Massachusetts' public colleges and universities found that 37 percent of graduates from public high schools in the Commonwealth enrolled in at least one remedial course in college. More than half of African-American, Latino and low-income college students required remedial education.[71] Improving pre-college preparation for undergraduate degree programs in science, technology, engineering and math (STEM) fields has been a major focus of Governor Deval Patrick's Readiness Project. Implementation of the project's recommendations will be a critical step toward increasing the number and diversity of undergraduate majors in STEM fields.

Implement recommendations of Commonwealth Transfer Advisory Group to facilitate and increase transfer of students from 2-year to 4-year degree programs in STEM fields

Associate degree programs in science, technology, engineering and math could play a more important role in expanding the pipeline of Massachusetts residents with bachelor's degrees in fields relevant to jobs in the life sciences. However, students who want to transfer credits from Massachusetts community colleges to four-year degree programs face uncertainty and obstacles. The Massachusetts Department of Higher Education established the Commonwealth Transfer Advisory Group to evaluate the Commonwealth's current credit transfer policies and practices; diagnose barriers facing students; compare and assess policies and practices enacted in other states; recommend policies and practices to remedy transfer barriers; and identify costs associated with proposed solutions.[72] Implementation of the Advisory Group's recommendations, which are scheduled for release in Spring 2008, are another important step toward generating a larger and more diverse pool of Massachusetts residents with bachelor's degrees in STEM fields.

Implement programs to improve retention in bachelor's degree programs in life sciences

Massachusetts needs to increase the number of domestic students who complete undergraduate courses of study in the science, technology, engineering and math fields that feed the pipeline of entry-level professional workers in the industry. According to members of the LSTI Academic Task Force, Massachusetts has not devoted sufficient resources to academic advising, tutoring, facilitated study groups and other programs designed to address high attrition rates of students in undergraduate degree programs in science. Increased investment in retention programs, especially targeting low income, minority and first-generation college students, is another important component of a strategy to increase the size of the state's life sciences workforce.

[71] Massachusetts Board of Higher Education, Massachusetts Department of Education, February 2008.
[72] Massachusetts Department of Higher Education website, <http://www.mass.edu/currentinit/currentinitCTAG.asp>

Increase financial assistance to undergraduates

A 2006 study by the Massachusetts Board of Higher Education found that the cost of attending a public four-year college in the Commonwealth was 34 percent higher than in the nation as a whole. The report documented high levels of unmet financial need among Massachusetts undergraduates, and increasing levels of student indebtedness. It also noted that more than 25 percent of full-time students aged 16-24 work more than 20 hours per week to finance academic and living expenses.[73] Members of the LSTI academic task force explained that students who work twenty hours or more are at a particular disadvantage in successful completion of science majors, which typically require more hours of study and laboratory time than concentrations in non-science fields.

The Board of Higher Education financial aid study explicitly recognized the high cost of undergraduate education as a problem affecting the state's workforce, and called for the use of incentive-based financial aid programs as an economic development strategy. Study recommendations included offering graduated loan forgiveness to students who have state-funded college loans and who are employed in occupations addressing critical workforce needs, including STEM fields, and providing tax credits to employers who offer student loan repayment programs.[74] The authors of the study envisioned "a program whereby students would apply to the state for forgiveness of a portion of their state-funded student loan debt in exchange for agreeing to work in jobs where there is a high demand for skilled labor," and noted that such a policy could be expanded to include federal or private student loans.[75]

Improve undergraduate preparation for careers in life sciences

Expand opportunities for practical training as part of undergraduate education

Life sciences employers interviewed and surveyed for LSTI identified internships and cooperative education programs as one of the most effective strategies to prepare undergraduates for jobs and careers in the industry. Industry representatives were unanimous in emphasizing the value of long term paid work experiences—lasting more than three months—for both the employer and the student. The Northeastern University Cooperative Education program, which allows students to complete up to three 6-month, full time job assignments as part of their undergraduate education, was singled out an excellent model. Medical device industry representatives described stiff competition among employers to hire Northeastern University coop students. A program at UMass Lowell, which allows students to earn credit for full-time work in the summer and continue on a part-time basis during the academic year, was suggested as a successful alternative to a long-term full-time placement.

Industry and higher education representatives involved in the Life Sciences Talent Initiative expressed unanimous support for expanding opportunities for cooperative education as part of the undergraduate experience. They noted, however, that the cost and administrative resources to establish and operate practical education programs are a significant challenge, especially for small companies and for higher education institutions where cooperative education is not a school tradition or a priority of current leadership.

As a result of the conversations facilitated by LSTI, the life sciences industry and higher education institutions have already begun working on new cooperative education initiatives. Industry associations can play a critical role in facilitating employer participation by surveying member interest in offering work placements for students and providing centralized administrative services, including a web-based listing of opportunities, a standard application form, application screening and guidelines on student orientation, management and evaluation. Higher education institutions can expand cooperative education opportunities for students by setting campus-wide policies on awarding credit for work placement, adjusting schedules to make it easier for students to work during

[73] Massachusetts Board of Higher Education, 2006.
[74] Ibid.
[75] Ibid.

the semester, and offering advising services to prepare students for their work placement. Colleges should also explore the possibility of offering campus housing and student health insurance to students who elect a full-time experience during the academic year.

The Massachusetts Board of Higher Education STEM Scholar Intern Program provides financial support for college students pursuing the fields of science, technology, engineering, and mathematics to increase the pipeline of future STEM workers in Massachusetts. The program received $2.5 million in funds from the 2006 Economic Stimulus Bill. Additional funding for this program may be required to encourage more students to participate in cooperative education experiences.

LSTI LEADS TO ACTION: GENZYME/UMASS SCHOLAR INTERN PROGRAM

At the Life Sciences Talent Summit, Genzyme Corporation and the University of Massachusetts announced the Genzyme/UMass Scholars program. Beginning in 2008, the pilot program offered summer jobs at Genzyme to ten juniors from the four UMass undergraduate campuses through a competitive application process. Students who completed the summer placement received $5,000 scholarships from Genzyme, and consideration for placement in a permanent job at the company following graduation. They were also eligible to apply for additional scholarship aid from the Massachusetts Department of Higher Education STEM Scholar Intern Program.

Student interest in the Genzyme-UMass pilot program was high, and Genzyme received more applications from highly-qualified students than it could accept. As a result, the Massachusetts Biotechnology Education Foundation is organizing focus groups of life sciences employers and higher education representatives to discuss expansion of undergraduate internship programs for the 2008-2009 academic year.

Strengthen the interdisciplinary curriculum and experiential learning programs in undergraduate education

Academic literature on preparing undergraduates for careers in biological science emphasizes the importance of concept-based integrated science courses and practical, hands-on laboratory experiences that expose students to the process of discovery and encourage them to solve real-life problems. To the extent that they have not already done so, all Massachusetts higher education institutions should review course offerings and curriculum in undergraduate science departments in an effort to provide these types of experiences for students.

Academic advisors to LSTI emphasized the need for new resources to improve science offerings (see box on challenges, below). The Commonwealth could address this need by sponsoring a competitive curriculum development grant program, and providing incentives for industry investment in undergraduate education in the form of providing adjunct faculty and support for purchase or donation of supplies and equipment.

Encourage and support independent undergraduate research

Undergraduate institutions can encourage and support student research by setting expectations that science majors complete at least one independent research project. Life sciences employers can participate by sponsoring student research projects and encouraging employees to serve as mentors to undergraduates.

CHALLENGES OF OFFERING INTEGRATED AND PROJECT-BASED LIFE SCIENCES COURSES

With support from the Howard Hughes Medical Institute, the UMass Amherst Biology Department has developed a series of four integrated laboratory science classes for upper-level undergraduate honors students. While these courses have been successful, they have also been very resource-intensive. With declining numbers of faculty positions and lack of dedicated University funding to offer laboratory courses, the Department would be unable to offer these types of courses without grant funding. Elizabeth Connor, UMass Associate Professor of Biology, HHMI Project Director and member of the LSTI Advisory Committee describes the financial and administrative challenges of offering integrated laboratory science courses:

Interdisciplinary Team Teaching: Coordination between instructors of any team-taught course is a challenge. We have discovered, however, that interdisciplinary team teaching brings with it a unique set of challenges since members of the team often span departments and even colleges within the university. In reality, the teaching of an interdisciplinary course is often a higher priority for the training of students in one instructor's department versus the other. In an environment of restricted resources, departments are under increasing pressure to serve their own student base and frequently the teaching of interdisciplinary courses does not achieve this goal. We recently encountered this issue in scheduling the fall 2007 offering of the interdisciplinary laboratory course, Gene and Genome Analysis (initially developed and taught by an instructor team from Biology and Microbiology). Due to course staffing demands, the Microbiology Department agreed to the participation of their faculty member in the interdisciplinary course under the condition that it be taught as an overload, in addition to Microbiology teaching responsibilities. As this was an unreasonable load for an untenured junior professor, the course is currently taught by a single instructor.

Equipment: A large investment in equipment is required. Students work in small teams or pairs. While some equipment is shared by the class, other components are required for each team or pair of students. Equipment costs for 20 students (10 teams of 2) in Gene and Genome Analysis were approximately $100,000; equipment costs for 18 students (6 teams of 3) in Bioimaging were approximately $250,000.

Faculty: Project-based courses are small and require faculty interaction and guidance. Our courses meet twice a week in lab for 3-4 hours with a faculty member, teaching assistant and the laboratory support instructor. The average ratio of instructor/students for these classes is currently 3:1. I am sure this can be expanded somewhat with planning and experience but this where we are now. In addition, the students produce four to six 20-page lab reports each a semester that the faculty instructor is required to grade.

Support personnel: To run these project-based courses requires significant course organization and support. We could not offer these courses without staff support. Our HHMI-funded staffer supports the 4 HHMI courses and one other course. The Biology Department currently has no staff devoted to supporting upper level courses with labs. This makes it particularly difficult to offer rich laboratory experiences to our students-even if grant funds are obtained to purchase the equipment.

Supplies: Cellular and Molecular Biology is expensive when compared to field or organismal-level work. On average, the Gene and Genome Analysis course costs approximately $6,000/semester or $300/student in supplies.

Encourage more undergraduates to develop basic knowledge and interest in the life sciences through courses and minors

Career opportunities in Massachusetts life sciences companies are growing in a variety of fields outside of the STEM disciplines, including legal and regulatory affairs, sales, marketing and corporate communications, and financial management occupations such as accounting. Employers emphasize that they need workers with education and skills in all of these areas. Undergraduates who develop interest and basic literacy in science through introductory courses and minors in colleges may be well-placed to enter jobs in the industry with very good opportunities for career advancement.

Technical Training

Special attention needs to be given to exploring the potential for developing life sciences career opportunities for workers with less than a bachelor's degree. While research conducted for LSTI does not provide clear guidance on future opportunities for these workers; industry experts involved in the study believe that more can be done to develop technical education and training programs that prepare young workers for skilled labor positions and help incumbent workers meet the changing needs of their employers. More research is needed to identify and describe the specific education, training and skill requirements for life sciences occupations that could potentially be filled by workers with less than a four-year degree.

Life sciences employers and educational institutions should develop partnerships to address current shortages in the manufacturing workforce and identify additional opportunities in the industry for workers with less than a four-year degree.

Strengthen partnerships between vocational-technical schools and the medical device industry to produce more entry-level workers for manufacturing jobs

Massachusetts medical device companies continue to employ skilled workers in traditional trades, such as machining, but there has been a decline in the number of young Massachusetts studying these trades in high school. Vocational-technical schools can play an important role in meeting the medical device industry's ongoing need for skilled workers. Employers should work closely with local vo-tech schools in developing curriculum and ensuring adequacy of equipment for training purposes. Community colleges can serve vo-tech grads and employers by providing on-going part-time academic programs emphasizing quantitative, computational, design and engineering skills, to help incumbent workers stay current and maximize long-term career flexibility.

Identify education and skill requirements and improve training programs for other manufacturing, technical and support positions

Representatives of community colleges and workforce training programs involved in LSTI emphasized their desire and capacity to provide courses of study to meet the needs of the life sciences industry. The existence of eight community colleges programs in biotechnology is a strong testament to the enthusiasm in the system to train students for jobs in the life sciences. In order to do so, however, community colleges need better guidance from employers on the types of jobs for which industry expects strong, sustained demand, and specific information on the education and skill requirements for these jobs. Other states, most notably North Carolina and California, have developed statewide community college initiatives to train workers for careers in biotechnology. While Massachusetts community colleges are willing to engage in a similar initiative, they should not do so without a commitment from industry to hire graduates who meet pre-determined standards of academic performance and technical competence.

Increase financial and academic support to community college students and incumbent workers in life sciences industry to allow them to earn undergraduate degrees

A community college education in Massachusetts is even more expensive in comparison to the cost of credits at public two-year colleges in other states than a four year degree. On average, tuition and fees at Massachusetts community colleges are almost 50 percent higher than at comparable institutions nationwide.[76]

The 2006 Massachusetts Board of Education Task Force report on financial aid called for the Commonwealth to "commit to providing a cost-free community college education for Massachusetts residents who complete a rigorous curriculum, complete early assessment, and enter college within six months of high school graduation." It also recommended that grant assistance be targeted to students enrolled in non-degree and certificate programs specific to industry and workforce needs.[77]

Identify transferable knowledge and skills from other industries and support targeted re-training programs

At the Life Sciences Talent Summit, participants identified several successful instances of Massachusetts biotechnology companies recruiting and retraining workers from other industries, including chemical and food processing companies and breweries. The Commonwealth's workforce investment boards, career centers and other programs housed under the Department of Labor and Workforce Development have the skills and resources to help connect displaced workers with potential employers in the life science industry.

K-12 STEM Pipeline

While the scope of research for the Life Sciences Talent Initiative did not include issues at the elementary and secondary education levels, the educators and employers involved in the project consistently and insistently stressed improving preparation and motivation of K-12 students in STEM fields as a top priority. They emphasized that more public outreach is needed to promote the variety of exciting, challenging, rewarding and financially attractive careers available in the Massachusetts life sciences industry, and that K-12 outreach and education programs should be specifically designed to increase the number of female, African-American and Latino students entering higher education in STEM fields. Efforts to address K-12 STEM pipeline issues in Massachusetts could benefit from increased participation by life sciences employers.

Improve Communication and Coordination Between Industry and Higher Education

The Commonwealth needs to strive for the same excellence in producing scientific and professional talent *across* the education and training system as it has achieved *within* individual colleges and universities. More communication, coordination and cooperation is needed between schools and educators at all levels — K-12, community colleges, public and private four-year colleges and universities — as well as between educational institutions and employers to ensure that more Massachusetts students are well-prepared to take advantage of opportunities in one of the state's most dynamic industries, and that life sciences employers continue to be able to find the talent they need here. New approaches must be built on the knowledge and expertise of both educators and employers and will require increased resources from both the public and private sectors.

[76] Massachusetts Board of Higher Education, 2006.
[77] Ibid.

The Governor's Readiness Project can guide efforts to develop closer relationships between educational institutions and employers. Key proposals of the Readiness Project include: better integration of primary, secondary, and higher education curricula; improvement in public higher education coordination; creation of a Business/Education Taskforce to develop consensus on the education/training needed for college and the 21st century workplace; and expanding partnerships with industry to provide internships and other school-to-career opportunities for students.

Engage employers and educators in a systematic review of existing education and training programs and curricula; determine need for improvement and new efforts based on current understanding of life sciences labor market

Currently, most collaboration between Massachusetts employers and educators on preparing students for careers in the life sciences occurs between individual companies and educational institutions. Sometimes, communication and cooperation is limited to relationships between a single company official and an individual faculty member. While one-to-one relationships between employers and schools can help meet short-term company needs for specific types of workers, such as technicians, they are an unstable basis on which to build academic programs, and they cannot address the growing demand for talent in important functional areas, such as clinical research, across the industry statewide.

Massachusetts life sciences employers need to work collectively to identify the education, knowledge, experience, skills and attributes required to succeed in functional areas where workers are difficult to find or retain across the industry, as well as for positions where companies are currently required to do extensive in-house training. Job descriptions and requirements should be shared and discussed with representative groups of faculty and administrators from public and private education and training institutions. Working together, employers and educators can then review existing programs and curricula designed to prepare students for high-demand positions, and assess the need for expansion, modification, specialization and/or creation of new programs.

Given the priority that industry representatives involved in LSTI placed on developing programs and curricula targeted to specific employer needs, it might be most effective to focus initial collaborative efforts on workforce training, certificate, two-year and master's and professional degree programs, which are more specific and focused in preparing students for employment than undergraduate degree and doctoral programs.

Compile and maintain accurate information on Massachusetts higher education, training and career opportunities in life sciences and make it easily accessible to students and employers

Massachusetts colleges, universities and workforce training organizations offer a wide variety of educational opportunities to prepare for careers in the life sciences, but finding current, accurate information about these programs can be challenging. Higher education institutions need to do a better job of ensuring that information about life sciences degree programs, courses, facilities and other resources is easy to find on campus websites. In addition, the state needs an electronic clearinghouse providing access to information on all such programs across the Commonwealth. The statewide database should, at a minimum, be searchable by subject and level of program and name and location of institution. All program listings in the clearinghouse should include links to the sponsoring organization or institution, including a contact person for more information. The clearinghouse itself should be linked to statewide websites that provide general information on higher education and training institutions and programs, such as www.masscolleges.com.

LSTI LEADS TO ACTION: MASSACHUSETTS BIOTECHNOLOGY EDUCATION RESOURCE CENTER

The Massachusetts Biotechnology Education Foundation, which has been very successful in developing partnerships between K-12 schools and biotechnology companies, is well-positioned to expand its efforts at the college level. As a result of participation in the Life Sciences Talent Initiative, the Foundation has created an expanded website providing information on education and careers in biotechnology for students, educators and employers. The site includes searchable directories of Massachusetts colleges, universities and organizations that offer degree and training programs in fields relevant to life science careers, and is designed to let individual institutions post and update their own information. It provides information on careers in biotechnology as well as links to a variety of career planning resources and the Massachusetts Biotechnology Council's database of current job openings at member organizations. Resources for K-12 science teachers, including curriculum and information on grants, classroom guest speakers and externships are also available. MassBioEd Foundation is also working in cooperation with the Massachusetts Biotechnology Council and the Massachusetts Medical Device Industry Council to expand internship opportunities for college students in life sciences firms.

The MassBioEd Foundation invites educational institutions, corporations and industry associations to sign up as "resource partners" at <www.massbioed.org>, and post information about education and career opportunities.

Improve access to capital facilities and equipment for education and training through strategic master plan for investment in shared resources

Colleges, universities and conventional and vocational-technical high schools need modern laboratories and equipment to teach cutting-edge science and technology, but the cost of building and equipping these facilities exceeds available resources. The University of Massachusetts 5-year Capital Plan calls for $2.96 billion in spending between fiscal years 2008 and 2012; $1.23 billion, accounting for more than 41 percent of the total is for science and technology projects. Requests for science and technology facilities at state and community colleges exceed $500 million in current dollars.

It is unlikely that the Commonwealth will have the resources build and equip new science facilities at all public high schools, colleges and universities in the near future. However, faculty and student access to state-of-the-art laboratories and equipment could be greatly expanded if new public and private science education facilities were planned and programmed as regional resources to be shared by multiple institutions. The University of Massachusetts has already compiled a list of research facilities and equipment at all five campuses and is working on policies to facilitate shared use within the system. UMass Amherst also allows faculty in the five-college system, including Amherst, Hampshire, Mt. Holyoke and Smith colleges, to use its facilities.

LSTI recommends that the Commonwealth develop policies that provide strong incentives for secondary and higher education institutions to share new science facilities and equipment, and allow and encourage public-private partnerships in planning, funding and operating these facilities.

CONCLUSION AND NEXT STEPS

Research conducted for the Life Sciences Talent has resulted in a deeper understanding of the industry, its talent needs and the types of programs best-suited to meet those needs. The project brought together leaders in industry, education and government and generated a new spirit of collaboration between life sciences industry associations and companies, state officials and academic institutions. Key stakeholders for all of these sectors reached consensus on the need for a more collaborative, systemic approach to meeting the industry's workforce needs. Several new initiatives have already been developed as a result of the project, and study findings have informed development of comprehensive legislation to encourage growth of the Massachusetts life sciences industry.

Together, the data and findings summarized in this report and the new relationships built through LSTI serve as a foundation for implementation of recommendations to meet the life sciences industry's need for talent. In order to ensure that progress continues, the following additional work is needed:

Establishment of ongoing leadership to ensure implementation of recommendations

The Massachusetts Life Science Center is well positioned with the resources and authority to take the lead in developing a statewide strategy and providing incentives for educators and employers to work together in educating and training the next generation of life science innovators and workers (e.g., new curriculum, new degree programs, and expanded co-ops). With its leadership drawn from the highest levels of state government, industry, higher education and research institutions, and its working relationship with the Life Sciences Collaborative, the Center is well-poised to ensure that both the public and private sectors do their part. Industry associations, including the Massachusetts Biotechnology Council, the Massachusetts Medical Device Industry Council and the Massachusetts Biotechnology Education Foundation, will be critical partners in this effort. Academic medical centers and private higher education institutions are very important players on both the demand and supply side of talent in the Massachusetts life sciences industry, and their involvement in program development and implementation is also essential.

Establishment of specific goals and benchmarks and evaluation of progress in meeting them

This report identifies general talent needs in the life sciences industry and provides an overview of the state's current capacity to meet these needs. More work is needed to translate the findings and recommendations in this report to specific, measurable goals. For example, while there is broad consensus on the need for more clinical research professionals in Massachusetts, what specific types of expertise are needed and which degree or certificate programs could provide this expertise? How many graduates of these programs could the state's employers absorb over the next five years, and what resources are needed at the institutional level to ensure that programs will be able to meet this need?

Investment of new resources for life sciences education and workforce training programs and facilities

The Massachusetts Life Sciences Act, approved by the legislature and signed by Governor Deval Patrick in June 2008, provides $1 billion in funding over the next ten years to support the Commonwealth's leadership position in the life sciences industry. This report provides a guide and priorities for policy makers as they shape investment of those funds in higher education and workforce development programs over the next decade.

Investment in other areas is also critical for the industry

Research for the Life Sciences Talent Initiative focused on higher education and workforce development programs, and the recommendations in this report are therefore targeted to policies in these areas. However, employers involved in LSTI raised other important issues that will affect their ability to grow in Massachusetts, including but not limited to state policies on land use, housing, transportation and taxation, and federal immigration policy. Access to industrial and commercially zoned land for expansion, improvements in housing affordability and transportation infrastructure, business tax incentives and continued ability to hire foreign workers are important to maintaining the Commonwealth's competitive advantage in the life sciences, and it is critical that Massachusetts policy makers continue to support initiatives in these areas.

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APPENDIX A: PROJECT GOVERNANCE AND OVERSIGHT

Life Sciences Talent Initiative
Advisory Committee

Industry

Zoltan Csimma (Committee Chair)
Senior Vice President & Chief Human Resources Officer
Genzyme Corporation

Lance Hartford
Executive Director
Massachusetts Biotechnology Education Foundation

Greg Liposky
SVP Operations
GTC Biotherapeutics, Inc.

Detlev Biniszkiewicz
Head of Strategy
Novartis Institutes for Biomedical Research

Chris Perley
Managing Director
Wyeth Biotech

Amy Crawford
Director of Human Resources
INFRAREDx, Inc.

Karin Gilman
General Manager
Symmetry Medical/TNCO
(Current Chair of MassMEDIC)

Marie Tremblay
Senior Human Resources Representative
Medtronic

Barbara Willwerth
Director, Human Resources
IST – Innovative Spinal Technologies, Inc.

Lisa Zankman
Senior Vice President Human Resources
Beth Israel Deaconess Medical Center

Christopher H. Colecchi
Vice President
Research Ventures & Licensing
Partners HealthCare System, Inc.

Steven Richter
President & Chief Executive Officer
Microtest, Inc.

Kevin O'Sullivan
President and Chief Executive Officer
Massachusetts Biomedical Initiatives

Joan Wood
Senior Vice President of Leadership & Organizational Development
Genzyme Corporation

Miwa A. Watkins, SPHR
Human Resources
Cambridge Consultants Inc.

State Government

Daniel O'Connell
Secretary
Executive Office of Housing & Economic Development

Suzanne M. Bump
Secretary
Executive Office of Labor & Workforce Development

Nancy Snyder
President and Chief Executive Officer
Commonwealth Corporation

C. Stanley McGee
Assistant Secretary of Policy & Planning
Executive Office of Housing & Economic Development

Michael J. Rodrigues
Co-Chair, Legislative Biotechnology Caucus
Massachusetts House of Representatives

Marie P. St. Fleur
Vice-Chair, House Committee on Ways and Means
Massachusetts House of Representatives

Jack H. Hart
Co-Chair, Legislative Biotechnology Caucus
Massachusetts State Senate

Harriet Chandler
Assistant Vice-Chair, Senate Committee on Ways and Means
Massachusetts State Senate

K-12 Education
Anthony Bent
Superintendent
Shrewsbury Public Schools
Also Chair, Massachusetts Association of School Superintendents

Higher Education
Michael F. Collins
Chancellor
University of Massachusetts Medical School

Mary K. Grant
President
Massachusetts College of Liberal Arts
Also Chair, Massachusetts Association of State College Presidents

Carole Cowan
President
Middlesex Community College
Also Chair, Massachusetts Association of Community College Presidents

Dennis D. Berkey
President
Worcester Polytechnic Institute

Deborah T. Kochevar
Dean
Cummings School of Veterinary Medicine
Tufts University

Life Sciences Talent Initiative
Academic Task Force

University of Massachusetts Amherst
George Langford (Task Force Chair)
Dean, College of Natural Sciences & Mathematics

W. Brian O'Connor
Biology Department

Elizabeth Connor
Associate Professor of Biology

University of Massachusetts Boston
Richard Antonak
Vice Provost for Research

Marshall Milner
Executive Director
Science Training Programs

Carol Colbeck
Dean, Graduate College of Education

Greer Glazer
Dean, College of Nursing

Andrew Grosovsky
Dean, College of Science & Mathematics

University of Massachusetts Dartmouth
Paul Calvert, Director
PhD Program in Biomedical Engineering & Biotechnology

Bal Ram Singh
Professor & Dreyfus Teacher-Scholar
Department of Chemistry & Biochemistry

University of Massachusetts Lowell
Bryan Buchholz
Professor, Department of Work Environment

Carl Lawton
Director
Massachusetts Biomanufacturing Center

University of Massachusetts Lowell, cont.
Catherine Kendrick
Director of Corporate & Distance Market Development

University of Massachusetts Medical School
Anthony Carruthers
Dean, Graduate School of Biomedical Sciences

Robert Finberg
Chair, Department of Medicine

Carole Upshur
Professor, Department of Family Medicine

Judith K. Ockene
Professor of Medicine and Chief
Division of Preventive & Behavioral Medicine
Interim Vice Chancellor for Faculty Administration

UMass Online
Barbara A. Macaulay
Chief Academic Officer

Bridgewater State College
Jeffery A. Bowen
Associate Professor of Biology
Department of Biological Sciences

Fitchburg State College
George L. Babich
Professor of Biology

Christopher K. Cratsley
Associate Professor
Department of Biology & Chemistry

Framingham State College
Guy Crosby
Associate Professor of Chemistry & Food Science

Mass College of Liberal Arts
Monica Joslin
Dean of Academic Affairs

Salem State College
Tracy L. Ware
Professor, Department of Biology

Westfield State College
David Doe
Professor, Biology Department

Worcester State College
Ellen F. Fynan
Professor & Interim Chair
Department of Biology

Daron C. Barnard
Biology Department

Berkshire Community College
Frank Schickor
Assistant Professor of Biology

Bristol Community College
Vijay Raja
Division of Mathematics, Science & Engineering

Bunker Hill Community College
Bob Steeper
Chair of Science Department

Greenfield Community College
Brian Adams
Chair, Science Department

Teresa Jones
Biology Department

Massachusetts Bay Community College
Bruce Jackson
Chairman, Science Division

Samard Saman
Associate Professor of Life Sciences
Massachusetts Bay Community College

Middlesex Community College
Jessie Klein
Associate Dean for Math & Science

Mt. Wachusett Community College
Chuck Weitze
Dean of Science

Roxbury Community College
Frederic Bertley
Professor of Biological Sciences

Northeastern University
Todd Leach
Associate Dean
Academic Affairs & Graduate Education
School of Professional & Continuing Education

Worcester Polytechnic Institute
Eric W. Overstrom
Professor and Department Head
Dept. of Biology & Biotechnology
Director, WPI Life Sciences & Engineering Center

Stephen P. Flavin
Associate Provost & Dean
Corporate & Professional Education

Ad Hoc Member:

Lance Hartford
Executive Director
Massachusetts Biotechnology Education Foundation

Life Sciences Talent Initiative
Workforce Panel

Donald Anderson
Director
Workforce Central
Worcester

Nancy Brown
Executive Director
MetroNorth Regional Employment Board
Cambridge

Constance Doty
Director
Mayor's Office of Jobs and Community Service
Boston

Lucy Meadows
Director
Boston Health Care and Research Training Institute
Boston

Susan Moulton
Consultant

Joel Nitzberg
Director
Institute for Lifelong Learning & Community Building
Cambridge

Constance Phillips
Director
CityLab Academy at Boston University
Boston

Tim Sappington
Executive Director
North Central Massachusetts Workforce Investment Board

Navjeet Singh
Vice President, Research & Evaluation
Commonwealth Corporation
Boston

Daniel Singleton
Deputy Director
Mayor's Office of Jobs and Community Service
Boston

Nancy Snyder (Chair)
President and Chief Executive Officer
Commonwealth Corporation
Boston

Michael Truckey
Director
Franklin/Hampshire Career Center
Greenfield

John Witt
Program Manager
Just-a-Start Corporation
Cambridge

Life Sciences Talent Initiative
Steering Committee

Tom Chmura
Vice President for Economic Development
University of Massachusetts

Glen A. Comiso
Director of Life Sciences and Health
Massachusetts Technology Collaborative

J. Lynn Griesemer, Ed. D.
Associate Vice President for Economic Development
Executive Director, UMass Donahue Institute
University of Massachusetts

Michael Goodman, Ph.D.
Director of Economic &
Public Policy Research
UMass Donahue Institute

Lance Hartford
Executive Director
Massachusetts Biotechnology Education Foundation

Eric Heller, Ed.D.
Director, Research & Evaluation
UMass Donahue Institute

Jennifer James
Under Secretary of Workforce Development
Department of Workforce Development

C. Stanley McGee
Assistant Secretary of Policy & Planning
Executive Office of Housing & Economic Development

Eric Nakajima
Senior Policy Advisor
Executive Office of Housing and Economic Development

Peter Abair
Director of Economic Development
Massachusetts Biotechnology Council

Robin Sherman
Research Manager
UMass Donahue Institute

Nancy Snyder
President/CEO
Commonwealth Corporation

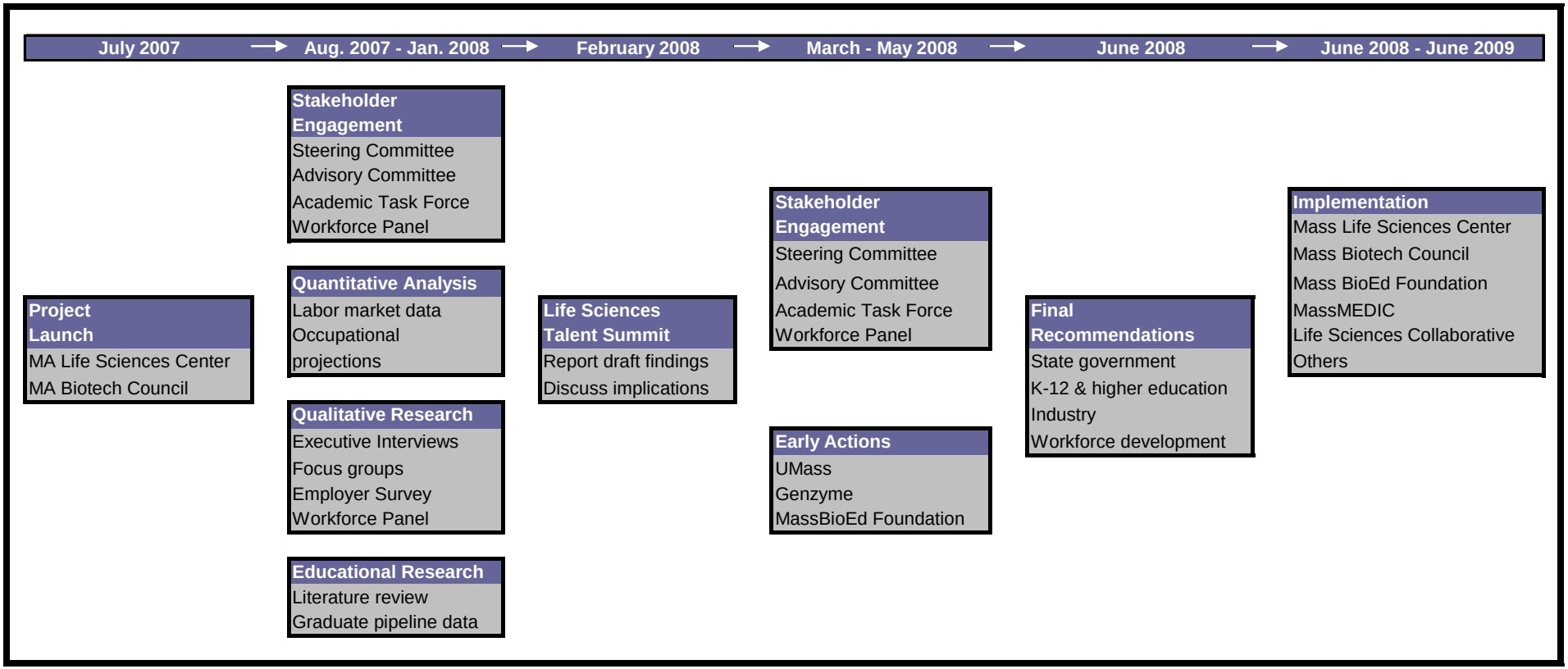
Thomas J. Sommer
President
Massachusetts Medical Device Industry Council

Mark Trusheim
Co-Bio Consulting

Melissa Walsh
Chief of Staff
Massachusetts Life Sciences Center

Christine R. Williams
Policy Advisor
Executive Office of Housing and Economic Development

APPENDIX B: LIFE SCIENCES TALENT INITIATIVE PROCESS AND TIMELINE



APPENDIX C: METHODOLOGY USED TO DEVELOP OCCUPATIONAL GROWTH PROJECTIONS

Key Points

Below are the key points necessary to understand and answer questions about the methodology UMDI used to derive occupational distribution estimates and growth projections for the life sciences study.

Method to produce estimates of 2006 occupational distribution of the life sciences industry in Massachusetts

- We started with the 2003 occupational distributions for the Commonwealth, available through the Department of Unemployment Assistance. We initially used these numbers because they were the only ones available through the DUA's website. However, after acquiring the 2005 occupational distributions (the most recent ones published by the Commonwealth), we determined that the 2003 data were actually more complete. This is presumably due to a higher response rate from employers in 2003, and thus a lower degree of suppression and more occupational detail in general. In any event, we determined that the 2003 data were both more detailed and more reliable, and thus decided to use them instead of the more recent 2005 dataset.
- Of course, we didn't want to use numbers from 2003, so we applied the proportions from the 2003 occupational matrices to the ES-202 industry level data for 2006. So, for example, if Occupation A made up 10% of Industry 1 in 2003, according to the 2003 occupational matrix, and the total employment in Industry 1 was, according to ES-202, 10,000, we would infer that there were 1,000 jobs in Occupation A in Industry 1 in 2006.
- We also didn't want to look at every occupation in the seven industry sectors we had identified as being involved in the life sciences industry.
    - Instead, we identified four of those seven industry sectors as being "pure" life sciences sectors, by which we meant that most of the work being done in those sectors by employees in our occupations of interest was directly related to the life sciences industry.
        - These four sectors (at the four digit level) were: 3254 (Pharmaceutical and Medical Manufacturing), 3345 (Navigational, Measuring, Electromedical, and Control Instruments Manufacturing), 3391 (Medical Equipment and Supplies Manufacturing), and 5417 (Scientific Research and Development).
        - For these sectors, we used the proportions that we had derived from the 2003 Massachusetts Occupational Matrices, as described above.
    - For the other three sectors in which we were interested, we had to figure out a way in which to get only those portions of relatively large industry sectors that were dedicated to the life sciences industry. We accomplished this by identifying "core occupations" that we felt were representative of the proportion of the industries' total work that was dedicated to the life sciences. We determined what percentage of the total industry was accounted for by these "core occupations," and made the assumption that a corresponding proportion of other occupations within those industries were dedicated to life-sciences related work. If, for example, the core occupations made up 5% of Industry 2, we would assume that 5% of individuals employed in Occupation B (which is not a core occupation) in Industry 2 were actually engaged in life-sciences related work.

        - The industry sectors on which we performed this operation were (at the four digit level): 5413 (Architectural, Engineering, and Related Services), 6113 (Colleges, Universities, and Professional Schools), and 6221 (General Medical and Surgical Hospitals).
        - The occupations we chose as "core occupations" were (SOC code in parentheses): Biomedical Engineers (17-2031); Biochemists and Biophysicists (19-1021); Microbiologists (19-1022); Medical Scientists, except Epidemiologists (19-1042); Life Scientists, all other (19-1099); Biological Technicians (19-4021); Chemical Technicians (19-4031); and Life, Physical, and Social Science Technicians, all other (19-4099).
        - By looking at the above-listed occupations in the previously mentioned industry sectors, we arrived at the following estimates of the proportions of non-core occupations in those sectors dedicated to life sciences-related work:
            - Architectural, Engineering, and Related Services (5413) – 3.3%
            - Colleges, Universities and Professional Schools (6113) – 4.6%
            - General Medical and Surgical Hospitals (6221) – 1.5%
        - We then simply multiplied the proportions we had received from the state data for those other occupations by the above modification factors to determine the proportion of each of those industries that was made up by individuals in a given occupation working *in the life sciences*.
    - After we had completed that operation, we still had to determine a list of occupations in which we were primarily interested, so we ranked the occupations in each industry sectors (using the modified numbers for those sectors that were not "pure" life sciences), and compiled a list of all occupations that made up at least 2% of any one sector. This allowed us to arrive at the list of 112 "critical" life sciences occupations that appear in Appendix D.

Method to produce growth projections of Massachusetts life sciences occupations

- By using the above-described methods, we had produced an estimate of the 2006 occupational distribution of the life sciences industry in Massachusetts. However, we also wanted to produce projections. Projections are available, on the state and the national levels, for the period 2004 through 2014. We were able to get state level industry specific occupational growth projections for this period for all of the industries in which were interested from the Division of Unemployment Assistance. However, it should be noted that two of these sets of industry-level projections are actually projections at the three-digit NAICS level. These are:
    - 325 (Chemical Manufacturing) instead of 3254 (Pharmaceutical and Medical Manufacturing), and
    - 622 (Hospitals) instead of 6221 (General Medical and Surgical Hospitals)
    - We did not consider this to be a substantial introduction of error because we were focused on specific occupations within these industries (our identified "core" and "critical" occupations) that were most likely to be found in the portions of these three-digit industry sectors in which were most interested.
    - Once we had these data, it was a relatively simple matter to apply the occupation- and industry-specific growth projections to our occupations of interest. We applied this growth to each occupation within its own industry, and then aggregated the results. It's worth mentioning that we assumed linear growth, so we made eight-year (2006-2014) projections by annualizing the ten year projections we received, and then raising this annual growth projection to the power of eight, in order to compound this rate over eight years.
    - However, it wasn't as simple as it might have been, for the following reasons:
        - We didn't have industry specific projections for all of the occupations in which were interested. We solved this in one of the following ways for each instance in which we

encountered the problem. Solutions are listed in the order in which we preferred to use them:

- If there was more than one other Life Sciences sector for which projections were provided for a given occupation, we used an average of these projected growth rates,
- If there were no industry specific projections available, we used state level, non-industry-specific growth projections for those occupations,
- If neither option was available, we simply didn't project growth for those occupations in those industries.

- Additionally, there were situations in which we had projections for a given occupation in a given industry, but no initial information regarding the 2003 distribution of these jobs in those industries. When this was the case, we did one of the following, again in order of preference:
  - We used the less reliable 2005, industry-specific occupational matrices, or
  - We used the 2003 Massachusetts, non-industry-specific occupational matrices, or
  - We used the less reliable 2005 Massachusetts, non-industry-specific occupational matrices.
- Using the above steps, we were able to arrive at occupation- and industry- specific growth projections for our 112 occupations of interest.

- Finally, it was clear to us that there some jobs for which we did not have specific information (most likely due to data suppression) but that still contributed to the overall size and composition of the life sciences industry. In order to get at this number, we summed the 2-digit Standard Occupational Codes under which all 112 of our critical occupations fell, and compared the sum of these codes, on an industry level, to the sum of the individual occupations we had identified. The difference (about 15,075 in 2006) was the total employment in LS occupations about which we had no detailed data. When combined with employment about which we did have detailed data (another 84,082 jobs) we were able to arrive at an estimate of overall industry employment (about 99,157) and to say that our detailed analysis covers about 84.8% of those jobs (84082/99157).

APPENDIX D: CRITICAL AND CORE LIFE SCIENCES OCCUPATIONS

Table 26: 112 Critical life sciences occupations

SOC Code	SOC Description	2006 Population in Life Sciences Sectors	Occupation as Percent of Total Life Sciences Sector	Projected Increase in Demand, 2006-2014	Projected 8-year (2006-2014) Growth	Projected Annual Growth
19-1042	Medical Scientists	3,672	3.7%	917	25.0%	2.8%
15-1032	Computer Software Engineers, Systems Software	2,555	2.6%	707	27.7%	3.1%
23-1011	Lawyers	2,771	2.8%	579	20.9%	2.4%
15-1051	Computer Systems Analysts	2,017	2.0%	537	26.6%	3.0%
15-1031	Computer Software Engineers, Applications	1,889	1.9%	520	27.5%	3.1%
19-1021	Biochemists & Biophysicists	1,454	1.5%	421	28.9%	3.2%
19-4099	Life, Physical & Social Science Technicians	3,621	3.7%	373	10.3%	1.2%
17-2071	Electrical Engineers	2,095	2.1%	278	13.3%	1.6%
13-2011	Accountants & Auditors	1,845	1.9%	264	14.3%	1.7%
13-1111	Management Analysts	1,510	1.5%	250	16.6%	1.9%
17-2031	Biomedical Engineers	685	0.7%	243	35.6%	3.9%
11-1021	General & Operations Managers	2,334	2.4%	225	9.6%	1.2%
17-2072	Electronics Engineers, except Computer	1,089	1.1%	211	19.4%	2.2%
17-2141	Mechanical Engineers	1,495	1.5%	194	13.0%	1.5%
15-1081	Network Systems & Data Communications Analysts	321	0.3%	189	58.9%	6.0%
17-2112	Industrial Engineers	1,150	1.2%	186	16.2%	1.9%
17-3023	Electrical & Electronic Engineering Technicians	1,478	1.5%	186	12.6%	1.5%
11-9041	Engineering Managers	1,254	1.3%	177	14.1%	1.7%
19-4021	Biological Technicians	1,192	1.2%	173	14.5%	1.7%
13-1199	Business Operations Specialists, All Other	1,085	1.1%	171	15.8%	1.8%
41-4011	Sales Representatives, Wholesale & Manufacturing, Technical & Scientific Products	2,241	2.3%	163	7.3%	0.9%
43-6011	Executive Secretaries & Administrative Assistants	2,057	2.1%	163	7.9%	1.0%
51-2092	Team Assemblers	2,416	2.4%	163	6.7%	0.8%
15-1071	Network & Computer Systems Administrators	544	0.5%	149	27.4%	3.1%
23-2011	Paralegals & Legal Assistants	804	0.8%	146	18.2%	2.1%
15-1041	Computer Support Specialists	1,396	1.4%	141	10.1%	1.2%
11-1011	Chief Executives	1,004	1.0%	136	13.6%	1.6%
11-2021	Marketing Managers	973	1.0%	122	12.5%	1.5%

SOC Code	SOC Description	2006 Population in Life Sciences Sectors	Occupation as Percent of Total Life Sciences Sector	Projected Increase in Demand, 2006-2014	Projected 8-year (2006-2014) Growth	Projected Annual Growth
11-3021	Computer & Information Systems Managers	730	0.7%	121	16.6%	1.9%
19-1022	Microbiologists	548	0.6%	120	21.9%	2.5%
29-1111	Registered Nurses	711	0.7%	119	16.8%	2.0%
11-3031	Financial Managers	930	0.9%	102	10.9%	1.3%
19-2031	Chemists	807	0.8%	88	10.9%	1.3%
19-1099	Life Scientists, all other	631	0.6%	87	13.8%	1.6%
17-2199	Engineers, All Others	922	0.9%	85	9.3%	1.1%
17-2061	Computer Hardware Engineers	725	0.7%	73	10.1%	1.2%
43-4171	Receptionists & Information Clerks	495	0.5%	73	14.7%	1.7%
17-3024	Electro-Mechanical Technicians	330	0.3%	72	21.7%	2.5%
43-3031	Bookkeeping, Accounting, & Auditing Clerks	1,578	1.6%	71	4.5%	0.6%
15-1061	Database Administrators	188	0.2%	66	34.9%	3.8%
17-3026	Industrial Engineering Technicians	329	0.3%	61	18.7%	2.2%
43-9061	Office Clerks, General	1,654	1.7%	61	3.7%	0.5%
11-2022	Sales Managers	747	0.8%	60	8.1%	1.0%
51-9083	Ophthalmic Laboratory Technicians	728	0.7%	48	6.6%	0.8%
15-1011	Computer & Information Scientists, Research	217	0.2%	45	20.6%	2.4%
19-4031	Chemical Technicians	636	0.6%	44	7.0%	0.8%
31-9096	Veterinary Assistants & Laboratory Animal Caretakers	372	0.4%	40	10.7%	1.3%
13-1071	Employment, Recruitment, & Placement Specialists	231	0.2%	39	16.8%	2.0%
19-2032	Materials Scientists	277	0.3%	39	13.9%	1.6%
13-2051	Financial Analysts	455	0.5%	35	7.6%	0.9%
43-4051	Customer Service Representatives	1,420	1.4%	34	2.4%	0.3%
11-3011	Administrative Services Managers	390	0.4%	30	7.7%	0.9%
13-1023	Purchasing Agents, Except Wholesale, Retail, & Farm Products	744	0.8%	28	3.8%	0.5%
11-3061	Purchasing Managers	255	0.3%	28	10.8%	1.3%
11-2031	Public Relations Managers	243	0.2%	27	11.0%	1.3%

SOC Code	SOC Description	2006 Population in Life Sciences Sectors	Occupation as Percent of Total Life Sciences Sector	Projected Increase in Demand, 2006-2014	Projected 8-year (2006-2014) Growth	Projected Annual Growth
43-1011	First Line Supervisors/Managers of Office & Administrative Support Workers	924	0.9%	26	2.9%	0.4%
15-1099	Computer Specialists, All Other	254	0.3%	26	10.3%	1.2%
11-9199	Managers, All Other	628	0.6%	22	3.4%	0.4%
41-9011	Demonstrators & Product Promoters	163	0.2%	20	12.1%	1.4%
29-1131	Veterinarians	179	0.2%	18	10.2%	1.2%
17-1022	Surveyors	179	0.2%	17	9.7%	1.2%
25-1071	Health Specialties Teachers, Postsecondary	111	0.1%	17	15.1%	1.8%
43-3011	Bill & Account Collectors	186	0.2%	17	9.0%	1.1%
13-2031	Budget Analysts	146	0.1%	17	11.4%	1.4%
17-3027	Mechanical Engineering Technicians	110	0.1%	16	14.3%	1.7%
51-9081	Dental Laboratory Technicians	429	0.4%	11	2.7%	0.3%
51-9082	Medical Appliance Technicians	167	0.2%	10	6.3%	0.8%
29-2012	Medical & Clinical Laboratory Technicians	81	0.1%	9	11.7%	1.4%
15-1021	Computer Programmers	1,081	1.1%	7	0.7%	0.1%
25-1021	Computer Science Teachers, Postsecondary	48	0.0%	7	15.2%	1.8%
25-1042	Biological Science Teachers, Postsecondary	48	0.0%	7	15.0%	1.8%
51-6031	Sewing Machine Operators	143	0.1%	7	5.0%	0.6%
51-4011	Computer-Controlled Machine Tool Operators, Metal & Plastic	316	0.3%	7	2.1%	0.3%
29-2011	Medical & Clinical Laboratory Technologists	58	0.1%	7	11.2%	1.3%
11-9021	Construction Managers	134	0.1%	6	4.8%	0.6%
25-1022	Mathematical Science Teachers, Postsecondary	39	0.0%	6	14.9%	1.7%
11-9111	Medicine & Health Services Managers	64	0.1%	6	8.9%	1.1%
29-2055	Surgical Technologists	21	0.0%	3	16.2%	1.9%
51-9061	Inspectors, Testers, Sorters, Samplers, & Weighers	1,372	1.4%	3	0.2%	0.0%
51-2099	Assemblers & Fabricators, All Other	351	0.4%	3	0.8%	0.1%

SOC Code	SOC Description	2006 Population in Life Sciences Sectors	Occupation as Percent of Total Life Sciences Sector	Projected Increase in Demand, 2006-2014	Projected 8-year (2006-2014) Growth	Projected Annual Growth
51-9111	Packaging & Filling Machine Operators & Tenders	714	0.7%	3	0.4%	0.0%
31-9099	Healthcare Support Workers, All Other	30	0.0%	2	7.5%	0.9%
17-3013	Mechanical Drafters	114	0.1%	2	1.9%	0.2%
29-1069	Physicians & Surgeons, All Other	9	0.0%	1	14.1%	1.7%
29-2056	Veterinary Technologists & Technicians	8	0.0%	1	10.2%	1.2%
43-6013	Medical Secretaries	83	0.1%	1	0.6%	0.1%
29-1067	Surgeons	2	0.0%	0	13.9%	1.6%
17-3031	Surveying & Mapping Technicians	134	0.1%	0	0.1%	0.0%
29-9199	Health Professionals & Technicians, All Other (OES Only)	54	0.1%	0	0.0%	0.0%
11-3040	Human Resources Managers	470	0.5%	0	0.0%	0.0%
17-3099	Drafters, Engineering, & Mapping Technicians, All Other (OES Only)	344	0.3%	0	0.0%	0.0%
19-3021	Market Research Analysts	691	0.7%	0	0.0%	0.0%
11-3051	Industrial Production Managers	705	0.7%	-1	-0.1%	0.0%
29-2061	Licensed Practical & Licensed Vocational Nurses	49	0.0%	-3	-5.3%	-0.7%
51-4121	Welders, Cutters, Solderes, & Brazers	168	0.2%	-6	-3.4%	-0.4%
51-1011	First-Line Supervisors/Managers of Production & Operating Workers	1,058	1.1%	-6	-0.6%	-0.1%
43-5061	Production, Planning, & Expediting Clerks	597	0.6%	-7	-1.1%	-0.1%
51-4041	Machinists	540	0.5%	-8	-1.4%	-0.2%
51-9011	Chemical Equipment Operators & Tenders	132	0.1%	-8	-6.4%	-0.8%
51-9141	Semiconductor Processors	137	0.1%	-9	-6.7%	-0.9%
51-9199	Production Workers, All Other	137	0.1%	-12	-8.7%	-1.1%
43-9021	Data Entry Keyers	198	0.2%	-13	-6.6%	-0.9%
51-4072	Molding, Coremaking, & Casting Machine Setters, Operators, & Tenders, Metal & Plastic	305	0.3%	-15	-4.8%	-0.6%

SOC Code	SOC Description	2006 Population in Life Sciences Sectors	Occupation as Percent of Total Life Sciences Sector	Projected Increase in Demand, 2006-2014	Projected 8-year (2006-2014) Growth	Projected Annual Growth
51-4081	Multiple Machine Tool Setters, Operators, & Tenders, Metal & Plastic	296	0.3%	-22	-7.5%	-1.0%
51-2022	Electrical & Electronic Equipment Assemblers	1,139	1.1%	-23	-2.0%	-0.3%
43-5071	Shipping, Receiving, & Traffic Clerks	536	0.5%	-41	-7.6%	-1.0%
51-4031	Cutting, Punching, & Press Machine Setters, Operators, & Tenders, Metal & Plastic	350	0.4%	-54	-15.5%	-2.1%
43-6014	Secretaries, Except Legal, Medical, & Executive	1,882	1.9%	-60	-3.2%	-0.4%
43-9051	Mail Clerks & Mail Machine Operators	193	0.2%	-66	-33.9%	-5.0%
43-4151	Order Clerks	230	0.2%	-70	-30.5%	-4.5%
51-2023	Electromechanical Equipment Assemblers	809	0.8%	-79	-9.7%	-1.3%
43-5081	Stock Clerks & Order Fillers	494	0.5%	-98	-19.8%	-2.7%

Table 27: Summary of current employment and occupational growth projections, life sciences and other sectors

Description	2006 Population in Life Science Sectors	Occupation as Percent of Total Life Sciences Sector	Projected Increase in Demand, 2006-2014	Projected 8-year (2006-2014) Growth	Projected Annual Growth
LS Occupations in Life Sciences sectors that are greater than 2% of 2003 employment in any one sector for which data are available	84,082	80%	9,386	11.164%	1.3%
Other Occupations in LS Sectors for which no detailed data are available	15,075	14.35%	1,683*	11.163%*	1.3%*
Core Occupations Outside of LS Sectors	5,931**	5.64%	662*	11.163%*	1.3%*
Total Known and Unknown Occupations	105,088	100.0%	11,731*	11.163%*	1.3%*

* Assumes occupations for which detailed data are not available will grow at the same rate as the sector overall.
** Bureau of Labor Statistics, Occupational Employment Statistics
Totals may not sum exactly due to rounding.
Sources: Massachusetts Occupational Employment Distribution by Industry, September 2003; Massachusetts Occupational Employment Distribution by Industry, September 2005; US Bureau of Labor Statistics May 2003 State Occupational Employment and Wage Estimates – Massachusetts; US Bureau of Labor Statistics May 2005 State Occupational Employment and Wage Estimates – Massachusetts Massachusetts ES-202 Data, 2006; Massachusetts DUA Occupational Growth Projections, 2004 – 2014

Definitions of Core Life Sciences Occupations, Bureau of Labor Statistics

Biomedical Engineers: Apply knowledge of engineering, biology, and biomechanical principles to the design, development, and evaluation of biological and health systems and products, such as artificial organs, prostheses, instrumentation, medical information systems, and health management and care delivery systems.

Biochemists and Biophysicists: Study the chemical composition and physical principles of living cells and organisms, their electrical and mechanical energy, and related phenomena. May conduct research to further understanding of the complex chemical combinations and reactions involved in metabolism, reproduction, growth, and heredity. May determine the effects of foods, drugs, serums, hormones, and other substances on tissues and vital processes of living organisms.

Microbiologists: Investigate the growth, structure, development, and other characteristics of microscopic organisms, such as bacteria, algae, or fungi. Includes medical microbiologists who study the relationship between organisms and disease or the effects of antibiotics on microorganisms.

Medical Scientists, except Epidemiologists: Conduct research dealing with the understanding of human diseases and the improvement of human health. Engage in clinical investigation or other research, production, technical writing, or related activities.

Life Scientists, all other: All life scientists not listed separately.

Biological Technicians: Assist biological and medical scientists in laboratories. Set up, operate, and maintain laboratory instruments and equipment, monitor experiments, make observations, and calculate and record results. May analyze organic substances, such as blood, food, and drugs.

Chemical Technicians: Conduct chemical and physical laboratory tests to assist scientists in making qualitative and quantitative analyses of solids, liquids, and gaseous materials for purposes, such as research and development of new products or processes, quality control, maintenance of environmental standards, and other work involving experimental, theoretical, or practical application of chemistry and related sciences.

Life, Physical, and Social Science Technicians, all other: All life, physical, and social science technicians not listed separately.

Source: <www.onetcenter.org>

APPENDIX E : PARTICIPANTS IN FOCUS GROUPS AND INTERVIEWS

Participants in Executive Interviews

Deborah Dunsire
President and Chief Executive Officer
Millennium Pharmaceuticals
Cambridge, MA

Jeffrey Elton
Senior Vice President of Strategy and Global Chief Operating Officer
Novartis Institutes for BioMedical Research
Cambridge, MA

Richard Ganz
President and Chief Executive Officer
Omnisonics Medical Technologies, Inc.
Wilmington, MA

Karin Gilman
General Manager
Symmetry Medical/TNCO
Whitman, Massachusetts

John Hennessey
Executive Director and General Manager
AstraZeneca Research & Development
Waltham, MA

Richard Packer
President and Chief Executive Officer
Zoll
Chelmsford, MA

Steven Richter
President and Scientific Director
Microtest Labs
Agawam, MA

Henri Termeer
President, Chairman and Chief Executive Officer
Genzyme
Cambridge, MA

Mark Trusheim
President
Co-Bio Consulting
Acton, MA

Josef Von Rickenbach
Chairman of the Board and Chief Executive Officer
PAREXEL
Waltham, MA

Participants in Focus Groups

Pat Abbott
Venture Forward Partners

Mitch Adams
Massachusetts Technology Collaborative

Joe Alviani
Massachusetts Life Sciences Collaborative

Donald Anderson
Workforce Central

Lisa Anderson
Vertex Pharmaceuticals

Cynthia Bainton
Northeastern University

Joanne Beck
Abbott Bioresearch Center

Vic Becker
Phase Forward

Detlev Biniszkiewicz
Novartis Institutes for Biomedical Research

Paul Bleicher
Phase Forward

Kelley Boutin
Shire Pharmaceuticals

Michael Brandt
Parexel

Nancy Brown
Metro North Regional Employment Board

Cathy Carew
ActivBiotics, Inc.

Barbara Carter
TransForm Pharmaceuticals, Inc.

Tiffany Clark
Randstad USA

Michaela Clemence
Commonwealth Sciences, Inc.

Paula Cloghessy
NUCRYST

Michael Collins
University of Massachusetts Medical School

Glen Comiso
Massachusetts Life Sciences Collaborative

James Daly
Sepracor

Daniel DeSantis

Kathleen DiGangi
Formatech, Inc.

Constance Doty
Mayor's Office of Jobs & Community Service, City of Boston

Nava Duek
Inverness Medical Innovations, Inc.

Wendy Durkin
Aerotek Scientific LLC

Jack Fitzmaurice
Wyeth Biotech

Paula Freeman
AVANT Immunotherapeutics, Inc

Pearl Freier
Cambridge BioPartners

David Fritzsche
Bristol-Myers Squibb Medical Imaging, Inc.

Steve Gansler
Millennium Pharmaceuticals, Inc.

Gary Gottlieb
Brigham and Women's Hospital

Paul Harrington
Northeastern University

Elizabeth Higgins
Glycosolutions

Elizabeth Holland
BioProcessors Corporation

Andrew Imrie
Randstad USA

Deborah Jancourtz
Northeastern University

Tina Karunaratne
Integrated Project Management Company, Inc.

Colin Kennedy
Randstad USA

Dick Knight
Keystone Partners

Carl Lawton
Massachusetts Biomanufacturing Center

Andrew Levin
Immunetics

Greg Liposky
GTC Biotherapeutics, Inc.

Thomas McCullough
University of Massachusetts Medical School

Daniel McGowan
On Assignment Lab Support

Lucy Meadows
Boston Health Care & Research Training Institute

Lee Merrill
Targanta Therapeutics

Mary Feely Moriarty
Korn/Ferry International

Heather Morin
Archemix Corp.

Kathy Nicholson
NovaBiomedical

Joel Nitzberg
Institute for Lifelong Learning & Community Building

John Nystrom
Millennium Pharmaceuticals, Inc.

John Olson
Columbia Insurance Agency, Inc.

Catherine Ostrofsky
Aerotek Scientific LLC

Kevin O'Sullivan
Massachusetts Biomedical Initiatives

Chris Perley
Wyeth Biotech

Constance Phillips
CityLab Academy - Boston University

Christine Pierce
Columbia Insurance Agency, Inc.

Veronica Porter
Northeastern University

Paul Richards
Marsh Inc.

Jeannine Ripley
Bristol-Myers Squibb Medical Imaging, Inc.

David Ross
Avecia Biotechnology, Inc.

Houda Samaha
Organogenesis

Aaron Sandoski
Norwich Ventures

Pamela Saras
Millennium Pharmaceuticals, Inc.

Katherine Scott
Toler Rx Inc.

Jessica Sedan
On Assignment Lab Support

Anupendra Sharma
Siemens Ventures

Navjeet Singh
Commonwealth Corporation

Daniel Singleton
Mayor's Office of Jobs & Community Service, City of Boston

Maura Snow
Basilea Labs

Rachel Strauss
AstraZeneca R & D

Jordan Swift
Northeastern University

Greta Tinay
Massachusetts Technology Collaborative

Marie Tremblay
Medtronic Vascular

Katherine Turner
NUCRYST

Miwa Watkins
Cambridge Consultants

Julia Wilkins
The Device Company

Barbara Willwerth
Innovative Spinal Technologies, Inc.

John Witt
Just a Start Corporation

Judith Woolfson
Northeastern University

Carl Wooten
Sepracor

Rachel Yamartino
Worcester Polytechnic Institute

APPENDIX F: LSTI SURVEY

I. Life Sciences Talent Initiative Survey of Human Resources Professionals

Expiration 1/20/2008

LIFE SCIENCES TALENT INITIATIVE STUDY

This survey is being administered by the University of Massachusetts Donahue Institute as part of the Life Sciences Talent Initiative (LSTI). The LSTI is a comprehensive study sponsored by the Massachusetts Life Sciences Center, the Massachusetts Biotechnology Council and the University of Massachusetts that will inform the design and development of a collaborative statewide strategy among business, government and higher education to ensure that the Commonwealth's talent needs in the life sciences are met. This survey is designed to ensure that the study's recommendations reflect the input and needs of the diverse group of companies, organizations and institutions that make up the Commonwealth's Life Sciences sector. Please note that the LSTI definition of the Massachusetts Life Sciences cluster *excludes* the delivery of health care services.

We request that each company, organization, and institution receiving this survey submit only one (1) response. If applicable, please forward this survey to the person in your organization who is best able to answer questions related to employment in the life sciences and to offer feedback on proposed strategies to improve worker preparation for these positions.

We maintain the confidentiality of all survey respondents. Your participation in this study is voluntary, and no participants are ever identified. Survey results will only be reported in summaries without identifying any individuals. Only UMass Donahue Institute research staff will have access to individual survey responses.

If you have any questions about this survey or the Life Sciences Talent Initiative, please contact Robin Sherman (below).

We estimate this survey will take about 15 minutes to complete. Surveys will be accepted for analysis through January 20, 2008.

Thank you for your help!

Robin Sherman
LSTI Research Manager
Donahue Institute
University of Massachusetts

II. Organization Profile

1. This survey has been sent to multiple mailing lists to ensure that survey data reflect the human resource needs of all Massachusetts life sciences employers. There is thus a chance that more than one person in your organization will receive the survey. To address the possibility of duplicate responses, the survey requires you to fill in the name of your organization and your position. If we receive duplicate responses, researchers will include one response in the official tabulation and use duplicates to enhance understanding of industry needs. All responses will remain confidential.

☐ *Biotechnology*
☐ *Pharmaceuticals*
☐ *Medical devices*
☐ *Academic medical center*
☐ *Academic research center*
☐ *Contract research organization, clinical*
☐ *Manufacturing - Commercial scale*
☐ *Sales and marketing*
☐ *Company headquarters - World*
☐ *Company headquarters - United States*
☐ *Company headquarters - Corporate division*

Other (please specify)

---

3. Please provide the ZIP codes of your organization's research, manufacturing and office facilities located in Massachusetts.

a. _____
b. _____
c. _____
d. _____
e _____
f _____
g _____
h _____
i _____
j _____

II. Organization Profile continued

4. Approximately how many people does your organization (or division, if applicable) employ in Massachusetts? Please exclude workers predominantly engaged in providing direct health care services. Also, please round answers to Estimated Full-Time Equivalents (FTE's) in Massachusetts.

Two years ago _____

At the present time _____

5. Two years from now, how do you expect your organization's Massachusetts life sciences workforce to have changed?

☐ *Increase Substantially*

☐ *Increase Modestly*

☐ *Remain about the Same*

☐ *Decrease Modestly*

☐ *Decrease Substantially*

6. Which of the following functions does your organization perform or operate in Massachusetts? Please check all that apply.

☐ *Research*
☐ *Product design and development*
☐ *Human clinical trials*
☐ *Animal product testing*
☐ *Manufacturing - Pilot scale*
☐ *Manufacturing - Commercial scale*
☐ *Sales and marketing*
☐ *Company headquarters - World*
☐ *Company headquarters - United States*
☐ *Company headquarters - Corporate division*

Other (please specify)

_____

III. Workforce Information

7. Please estimate percentages (%) of your organization's Massachusetts workforce, by level of education.

% High school degree or less _____

% Associate's degree _____

% Bachelor's degree _____

% Master's degree _____

% Doctoral degree or terminal professional degree _____

8. How difficult is it for your organization to hire each of the following types of employees? How difficult was it three years ago?

	Current difficulty in hiring (dropdown box: very difficult, moderately difficult, not difficult)	*Compared to three years ago, is it more or less difficult to hire employees? (dropdown box: more, the same, less)*
Research Scientists		
Engineers		
Research Associates		
Clinical Research Staff		
Information Technology/Computer Specialists		
Technicians		
Manufacturing Staff		
Legal and Regulatory Staff		
Marketing and Sales Staff		

9. What is the most significant challenge to your organization's ability to hire new employees? (open-ended question)

10. What is the most significant challenge to your organization's ability to retain existing employees? (open-ended question)

IV. Potential Strategies to Meet Human Capital Needs in the Life Sciences

11. How useful would each of the following strategies be in helping you organization meet its human capital needs in Massachusetts?

	Usefulness (dropdown box: high/medium/low/na)
a. Increase industry input into higher education, workforce training programs, and curricula	
b. Implement targeted programs to increase the supply of workers for specific high-demand, hard-to-fill positions	
c. Conduct an annual human capital needs assessment of Massachusetts life sciences employers	
d. Increase emphasis on independent and applied research in higher education programs	
e. Increase emphasis on laboratory research and skills in higher education programs	
f. Increase programs to improve the skills of incumbent workers	
g. Increase training for workers displaced from other industries	
h. Increase student internship and co-operative education programs	
i. Expand English as a Second Language programs	
j. Provide financial incentives for students trained in life sciences to stay in Massachusetts	
k. Provide housing assistance to recruit and retain workers in high-demand positions	
l. Increase visas for foreign workers in high demand positions	
m. Promote life sciences careers to middle and high school students, parents and guidance counselors	
n. Promote life sciences careers to college students and career counselors	
o. Publicize current job openings in life sciences to students and recent graduates	

12. Which of these strategies (discussed above) should be the highest priority for implementation? Please rank up to five (5) strategies.

	First priority	*Second priority*	*Third priority*	*Fourth priority*	*Fifth priority*
a. Industry input in education	○	○	○	○	○
b. Targeted programs	○	○	○	○	○
c. Human capital needs assessment	○	○	○	○	○
d. Independent and applied research	○	○	○	○	○
e. Laboratory research and skills	○	○	○	○	○
f. Incumbent worker programs	○	○	○	○	○
g. Displaced worker programs	○	○	○	○	○
h. Student internships and co-ops	○	○	○	○	○
i. ESL programs	○	○	○	○	○
j. Student financial incentives	○	○	○	○	○
k. Housing assistance	○	○	○	○	○
l. Visas	○	○	○	○	○
m. Career information, K-12 students	○	○	○	○	○
n. Career information, college students	○	○	○	○	○
o. Publicize job openings	○	○	○	○	○

13. Do you have any other suggestions for any other state, academic or industry-sponsored programs or initiatives that could help your organization meet its human capital needs? (open-ended question)

V. Higher Education and Workforce Training

14. Which *public* colleges or universities in Massachusetts provide *the best* education and training for careers in the life sciences? (Please select up to three (3) schools from list of all public 4-year colleges and universities in Massachusetts provided in drop-down box.)

a. _____

b. _____

c. _____

15. Which *private* colleges or universities in Massachusetts provide *the best* education and training for careers in the life sciences? (Please enter up to three (3) schools, open-ended question.)

a. _____

b. _____

c. _____

16. Which *two-year* colleges in Massachusetts provide *the best* education and training for careers in the life sciences? (Please select up to three (3) schools from list of 2-year colleges provided in drop-down box.)

a. _____

b. _____

c. _____

17. Which *workforce training, corporate education, or other programs* provide *the best* education and training for careers in the life sciences? (Please enter up to three (3) programs, open-ended question.)

a. _____

b. _____

c. _____

18. Based on your responses to questions 15 through 18, please characterize how well you think Massachusetts' higher education and workforce training organizations prepare students for careers in the life sciences.

	Excellent	*Good*	*Fair*	*Poor*	*No opinion*
Public *four-year colleges and universities*	○	○	○	○	○
Private *four year colleges and universities*	○	○	○	○	○
Two-year *colleges*	○	○	○	○	○
Workforce training or corporate education programs	○	○	○	○	○

Any specific comments related to your choices? (open-ended question)

19. How well prepared are students from Massachusetts' public and private institutions for careers in the life sciences? (Please rate students at each level of education.)

	Excellent	*Good*	*Fair*	*Poor*	*No opinion*
PhD, MD, DVM, other professional	○	○	○	○	○
Master's degree	○	○	○	○	○
Bachelor's degree	○	○	○	○	○
Associate's degree or certificate	○	○	○	○	○
High school graduate/GED	○	○	○	○	○

20. Which public or private educational institutions or workforce training organizations *outside* Massachusetts provide *the best* education and training for careers in the life sciences? (Please list up to five (5) schools or programs.)

a. _____

b. _____

c. _____

d. _____

e. _____

VI. This completes the Life Sciences Talent Initiative Survey.

21. If you would like more information on the Life Sciences Talent Initiative, including an invitation to the Life Sciences Talent Initiative Summit with Governor Deval Patrick on February 1, 2008 at UMass Boston, please enter an email address below... and thank you!

We greatly appreciate your time and assistance!

APPENDIX G: DESCRIPTION OF LIFE SCIENCES FIELDS

The National Center for Education Statistics' Integrated Postsecondary Education Data System provides information on enrollment in and completion of courses of study by institutions and by academic or technical field. Information on courses of study is available at levels of 2-digit, 4-digit and 6-digit codes, in order of increasing specificity. For the purposes of describing the structure of Massachusetts life sciences education and training programs and the pipeline of graduating students, UMass Donahue Institute researchers selected 2-digit and 4-digit codes that provided the best match to life sciences occupations in Massachusetts, as shown below.

Life Sciences Fields of Study	Classification of Instructional Program (CIP) Code
Computer and information sciences and support services	
Computer and information sciences and support services (all 2- digit fields)	11.00
Engineering	
Engineering, General	14.01
Biomedical/Medical Engineering	14.05
Chemical Engineering	14.07
Computer Engineering, General	14.09
Electrical, Electronics and Communications Engineering	14.10
Engineering Mechanics	14.11
Engineering Physics	14.12
Engineering Science	14.13
Materials Engineering	14.18
Mechanical Engineering	14.19
Systems Engineering	14.27
Textile Sciences and Engineering	14.28
Polymer/Plastics Engineering	14.32
Industrial Engineering	14.35
Manufacturing Engineering	14.36
Operations Research	14.37
Engineering, Other	14.99
Engineering Technology/Technicians	
Engineering Technology, General	15.01
Electrical Engineering Technologies/Technicians	15.03
Electromechanical Instrumentation and Maintenance Technologies/Technicians	15.04
Industrial Production Technologies/Technicians	15.06
Quality Control and Safety Technologies/Technicians	15.07
Mechanical Engineering Related Technologies/Technicians	15.08
Engineering-Related Technologies	15.11
Computer Engineering Technologies/Technicians	15.12
Drafting/Design Engineering Technologies/Technicians	15.13
Engineering-Related Fields	15.15
Engineering Technologies/Technicians, Other	15.99

Life Sciences Fields of Study	Classification of Instructional Program (CIP) Code
Biological and Biomedical Sciences (all 2 digit fields, below, included)	
Biology, General	26.01
Biochemistry, Biophysics and Molecular Biology	26.02
Botany/Plant Biology	26.03
Cell/Cellular Biology and Anatomical Sciences	26.04
Microbiological Sciences and Immunology	26.05
Zoology/Animal Biology	26.07
Genetics	26.08
Physiology, Pathology and Related Sciences	26.09
Pharmacology and Toxicology	26.10
Biomathematics and Bioinformatics	26.11
Biotechnology	26.12
Ecology, Evolution, Systematics and Population Biology	26.13
Biological and Biomedical Sciences, Other	26.99
Mathematics and statistics	
Mathematics and statistics (all 2-digit fields)	27.00
Multidisciplinary studies	
Biological and Physical Sciences	30.01
Systems Science and Theory	30.06
Mathematics and Computer Science	30.08
Natural Sciences	30.18
Neuroscience	30.24
Physical Sciences	
Chemistry	40.05
Physics	40.08
Science Technologies/Technicians	
Biology Technician/Biotechnology Laboratory Technician	41.01
Physical Science Technologies/Technicians	41.03
Science Technologies/Technicians, Other	41.99
Health Professions and Related Clinical Services	
Clinical/Medical Laboratory Science and Allied Professions	51.10
Medical Clinical Sciences/Graduate Medical Studies	51.14
Pharmacy, Pharmaceutical Sciences, and Administration	51.20
Veterinary Medicine (DVM)	51.24

APPENDIX H: SUMMARY OF NOMINATED MODEL LIFE SCIENCES EDUCATION AND TRAINING PROGRAMS

Institution	Type of Program	Title of Program	Type of degree, if relevant	Notes
Beth Israel Deaconess Medical Center, Children's Hospital, New England Baptist Hospital, Bunker Hill Community College and Boston Private Industry Council	Undergraduate degree/Incumbent worker/career ladder	Boston Teaching Hospital Medical Laboratory Technician Initiative	AS	Collaboration between hospital employers and community college to provide onsite classes and practical training to working adults to qualify them for hard-to-fill positions and facilitate career advancement
Biomedical Science Careers Program	Career development and mentoring	Programs include student conferences & symposia, skill and career development programs, newsletter, resource directory, scholarships		Set of programs to increase the representation of minorities in the biomedical sciences and other science-related fields
Boston University	Workforce	CityLab Academy	Certificate	2-semester degree track academic and lab training program designed for high school graduates; targets underrepresented populations
Boston University	K-12 STEM and K-12 Teacher Training	CityLab STEM Academy		Includes two laboratories at BU and mobile laboratory used for teacher training and classes for students in grades 7-12.
Boston University	Undergraduate degree	Human Physiology	BS	Focus on human biology, includes practical experience

Bridgewater State College	Minor within undergraduate degree program	Biotechnology Minor		
Bridgewater State College	K-12 STEM and K-12 Teacher Training	CityLab/Center for the Advancement of Science Explorations		Offshoot of Boston University CityLab; also provides biotechnology-related summer education program for youth
Bridgewater State College	Independent research opportunity in undergraduate degree program	Adrian Tinsley Program and the Office of Undergraduate Research		Provides financial assistance and mentoring for undergraduate research
Bunker Hill Community College	Undergraduate degree	Biological Science/Biotechnology	AS	New program started in fall 07; offers transfer option to 4 year schools and option for direct employment in biomedical research labs.
Framingham State College	Undergraduate degree	Biochemistry	BS	4-year degree in Biochemistry, certification pending from American Chemical Society
Framingham State College	Required course for credit in undergraduate degree program	Methods in Biological Research I and II		Two-semester course in independent research, required for all biology majors
Harvard-MIT Health Sciences & Technology	Graduate degree	HST Biomedical Enterprise Program	MS/MBA	Interdisciplinary program to train scientist-entrepreneurs
Harvard-MIT Health Sciences & Technology	Graduate degree	HST Medical Engineering and Medical Physics	PhD	Interdisciplinary, translational research, designed to provide research scientists with training in medicine
Harvard-MIT Health Sciences & Technology	Professional degree	HST Medical Sciences Program	MD	Interdisciplinary, translational research, designed to prepare physicians for careers in clinical research
Just-a-Start	Workforce	Cambridge Biomedical Careers	Certificate	Trains low income, minority, unemployed/underemployed/displaced workers to enter careers in life sciences

Massachusetts Bay Community College	Undergraduate	Biotechnology	AS	Program promotes independent research and industry internships
Massachusetts Bay Community College	Undergraduate	Biotechnology: Forensic DNA Science	AS	Students learn DNA and mitochondrial DNA analysis through participation in actual criminal and anthropological cases involving DNA evidence collection and analysis.
Massachusetts Bay Community College	Undergraduate	Environmental Science and Safety	AS	Focuses on environmental science issues, such as air and water testing and analysis, industrial waste treatment, municipal wastewater treatment, and environmental law
Massachusetts College of Liberal Arts	Undergraduate degree concentration	Biology with concentration in Cytotechnology	BA	3+1 program with last year onsite at Berkshire Medical Center
Massachusetts College of Liberal Arts	Undergraduate degree concentration	Biology with concentration in Medical Technology	BA	3+1 program with last year onsite at Berkshire Medical Center
MassBioEd Foundation	Workforce/Incumbent worker	Biotech Learning Center: Biotech Project Management and Overview of Clinical Research	Certificate	Designed to serve industry needs for targeted training
MassBioEd Foundation	K-12 Teacher Training	Bioteach		Provides K-12 schools and teachers with knowledge and equipment to teach biotechnology
MassBioEd Foundation	Informational Resource	Education and Workforce Development Website		Comprehensive on-line resource for education and training programs in life sciences, will launch March 2008

Middlesex Community College	Undergraduate degree	Biotechnology	AS	Established program with industry advisory board, faculty have industry experience; schedule accomodates students already working in the industry
Middlesex Community College	Workforce	Biotechnology Technician	Certificate	Established program with industry advisory board, faculty have industry experience; schedule accomodates students already working in the industry; credits transfer to AS program
Northeastern University	Undergraduate degree option	Cooperative Education	BS	More than 300 undergraduates in life sciences employed in labs and industry through cooperative education program in 2007; graduates program in very high demand by employers
Northeastern University	Graduate degree	Health Informatics	MS	Interdisciplinary, IT focus, program new in 2007
Northeastern University	Graduate degree	Biotechnology	MS	Includes management course and internship, tracks in molecular, pharmaceutical and engineering biotechnology
Northeastern University	Graduate degree concentration	Nanomedicine Science & Technology IGERT (Integrative Graduate Education and Research Traineeship)	PhD	Interdisciplinary doctoral program in nanomedicine; internship and K-12 outreach required
Northeastern University	Undergraduate/Graduate/Professional degree program	Doctor of Pharmacy	PhD	6 year program for students admitted as freshmen, 4 years for post-undergrads; includes cooperative education
Northeastern University	NU Young Scholars Program	K-12 STEM Outreach		6-week summer research science program for high school students

Northeastern University	Post-doctoral fellowship	Critical Care Pharmacy Fellowship	Post-doc	New program (2004) to train ICU pharmacists with doctorates to conduct clinical and laboratory research; cooperative program with Tufts-NEMC
Northeastern University	Academic Research Center	Center for Drug Discovery	Post-doc	Graduate and post-doctoral training for future scientists in the field of Medications Development for Drugs of Abuse
Springfield Technical Community College	Undergraduate degree	Biotechnology	AS	Career and transfer options; internship opportunity available
Tufts University	Undergraduate degree	Biology	BS	Emphasis on independent research and internships
Tufts University/Cummings School of Veterinary Medicine	Graduate Degree	Laboratory Animal Medicine	DVM/MS	4 year MS/DVM program created 2004, unique in veterinary schools, collaboration with industry, summer practical and research training required
Tufts University/Cummings School of Veterinary Medicine	Course and electives within professional degree program	Accelerated Clinical Excellence Program	DVM	Designed to teach evidence-based veterinary medicine and practical skills needed to excel as a veterinary clinician
Umass Amherst	Undergraduate degree	Biochemistry and Molecular Biology	BS	Interdisciplinary program requiring competence in chemistry, biology, genetics, physics and mathematics
Umass Amherst	Course within undergraduate degree program	Biotechnology Process Engineering Laboratory		Students work in interdisciplinary teams to design a process to supply a protein-based product, teams include 2 life science and 2 engineering majors

Umass Amherst	Course within undergraduate degree program	Biological Imaging		Course in quantitative optical microscopy, research project component
Umass Amherst	Option within graduate degree program	Chemistry-Biology Interface	MS/PhD	NIH-funded interdisciplinary training program bridging biology and chemistry; required course in drug design
Umass Amherst	Graduate degree concentration	Institute for Cellular Engineering IGERT	PhD	NSF funded interdisciplinary training program new for 2008, will include Industry Consortium advisory group; 9 participating departments plus 4 interdisciplinary programs
Umass Amherst	Independent research opportunity in undergraduate degree program	Office of Undergraduate Research and Scholarship; Research Opportunities Fair; Undergraduate Science Research Symposium		Programs designed to encourage, support and facilitate independent research in sciences among undergraduates
Umass Amherst	Honors program within undergraduate degree program	Junior Fellows in the Life Sciences		Competitive fellowship for undergraduates conducting capstone research in life sciences; fellows receive financial award for research, mentoring, and present results of research in symposium
Umass Amherst	Course within undergraduate degree program	Introduction to Biotechnology Laboratory		Students work in teams to learn current biotechnology techniques in hands-on laboratory modules
Umass Amherst	Teaching method	Active Learning in the Large Science Classroom		Use of website and in-class personal communication system device to enhance student engagement and class participation

Umass Amherst	Course within undergraduate degree program	Gene and Genome Analysis		Students apply principles of gene and genome analysis through investigation of unknown plant gene using combination of wet lab techniques, bioinformatics software, statistical analysis and other research
Umass Amherst	Curricular goals	Learning Goals for Life Sciences Majors		
Umass Amherst	Course within undergraduate degree program	Writing in Biology: Writing from Experience and Community Service		Students develop research proposals for community service project, perform the project in groups and write about the results
Umass Amherst	Teaching method for course in undergraduate degree program	Intro Biology: Preparation Page and Duck!		Web-based materials that enhance student ability to engage in high-level in-class problem-solving techniques
Umass Amherst	Teaching method for course in undergraduate degree program	Intro Biology Laboratory: Extended Inquiry using Data Aggregation		Data is aggregated across all laboratory sections and analyzed by students using computer-based problem solving environments
Umass Amherst	Teaching method for courses in undergraduate degree program	Model-Based Reasoning in Biology		Students construct understanding of biology by reasoning through problems centered on existing, well-established models of biological systems; teaching methods well-suited for large classrooms
Umass Dartmouth	Course within undergraduate degree program	Bioinformatics 455		Computer Science elective
Umass Dartmouth	Course within graduate degree program	Bioinformatics 555		Computer Science elective

Umass Intercampus--Boston, Dartmouth, Lowell, MassMed	Graduate degree	Biomedical Engineering and Biotechnology	MS/PhD	Intercampus collaboration, uses distance learning, includes capstone project in addition to thesis
Umass Lowell	Graduate degree and option within graduate degree program	Biology with Biotechnology option	MS	Focus on hands-on lab training; partially funded by Industry
Umass Lowell	Undergraduate degree and option within undergrad degree program	Biology with Biotechnology option	BS	Independent undergraduate research encouraged
Umass Lowell	Graduate degree	Clinical Laboratory Science	MS	Concentrations in Clinical Research, Health Informatics, Laboratory Administration, Nutritional Sciences, and Public Health Laboratory Science. Courses are scheduled to accommodate working professionals; many offered online.
Umass Lowell	Undergraduate degree	Clinical Laboratory Science	BS	Options in Medical Technology, Clinical Sciences and Nutritional Sciences. Emphasis on quantitative and laboratory skills.
Umass Lowell	Graduate certificate	Clinical Pathology	Certificate	Four course program for working professionals in industry; all courses available on campus or online.
Umass Lowell	Course in undergraduate and graduate degree programs	Biopharmaceutical Regulatory Compliance		
Umass Lowell	Course in undergraduate and graduate degree programs	Principles of Cell and Microbe Cultivation		Focus on practical approaches to state-of-the-art batch processing using bacterial, yeast and mammalian systems
Umass Lowell	Graduate Certificate	Biotechnology and Bioprocessing	Certificate	Laboratory and practical focus; program designed for working professionals with degrees

Umass Lowell	Course in undergraduate and graduate degree programs	Isolation and Purification		
Worcester Polytechnic Institute	Workforce	Fundamentals of Biotech Manufacturing	Certificate	Short-term training in cGMP facility, collaboration between state govt, industry & academia, initially targeted displaced workers
Worcester Polytechnic Institute	Workforce	Medical Device Management	Certificate	Short-term training for workers new to medical device industry, partnership between WPI and MassMEDIC
Worcester Polytechnic Institute	Undergraduate	Biomedical Engineering	BS	Project-based curriculum integrating physical, chemical, mathematical, and computational sciences and engineering principles
Worcester Polytechnic Institute	Undergraduate	Mechanical Engineering	BS	Students required to complete Major Qualifying Project to solve real-life problem, generally by working in teams
Worcester Polytechnic Institute	Workforce/Graduate	Bioscience Administration	Certificate	Onsite continuing education for incumbent workers, option to continue for MS degree
Worcester State College	Undergraduate degree	Biotechnology	BS	Interdisciplinary, interdepartmental program, independent research and internship options available; program has articulations with community colleges and graduates can continue in part-time MS program

APPENDIX I: LIFE SCIENCES TALENT SUMMIT AGENDA AND PARTICIPANTS

Life Sciences Talent Summit
Friday, February 1, 2008
University of Massachusetts Boston
Campus Center
7:30 am to 3:00 pm

Agenda

8:00 am **Opening Session**

Greetings
- Dr. J. Keith Motley, Chancellor, University of Massachusetts Boston

Welcome to the Summit
- Dr. Jack M. Wilson, President, University of Massachusetts

Introduction of Keynote Speaker
- Mitch Adams, Executive Director, Massachusetts Technology Collaborative

Industry Keynote Speaker
- Dr. Joshua Boger, Founder, President and Chief Executive Officer, Vertex Pharmaceuticals

8:30 am **Morning Plenary Session: Presentation of Life Sciences Talent Research**

Moderator:
- Zoltan Csimma, Senior Vice President and Chief Human Resources Officer, Genzyme and Chairman, Life Sciences Talent Initiative Advisory Committee

Presenters:
- Dr. J. Lynn Griesemer, Executive Director, UMass Donahue Institute and Associate VP for Economic Development, UMass President's Office
- Dr. Michael Goodman, Director of Economic & Public Policy Research, UMass Donahue Institute
- Robin Sherman, Life Sciences Talent Initiative Project Manager, UMass Donahue Institute

Responders:
- Dr. Mary K. Grant, President, Massachusetts College of Liberal Arts
- Nancy Snyder, President & CEO, Commonwealth Corporation
- Mark Leuchtenberger, President and Chief Executive Officer, Targanta Therapeutics and Vice-Chairman, Massachusetts Biotechnology Council

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10:30 am **Working Groups**

1. Filling the Pipeline: Shaping Curriculum and Programs to Produce Tomorrow's Scientists and Engineers

Co-Chairs:

- Senator Robert O'Leary, PhD, Senate Chair, Joint Committee on Higher Education
- Dr. Patricia Plummer, Chancellor, Massachusetts Board of Higher Education

Panelists:

- Dr. Paul Bleicher, MD and PhD, Founder and Chairman, Phase Forward
- Dr. Leo X. Liu, MD, Founder, President and CEO, Cambria Biosciences
- Dr. Dennis D. Berkey, PhD, President of Worcester Polytechnic Institute
- Constance Phillips, M.A., M.P.H, Director of CityLab Academy, Research Associate Professor of Biochemistry in Boston University's Metropolitan College and School of Medicine

Panel Moderator:

- Dr. George Langford, Dean, College of Natural Sciences & Mathematics, UMass Amherst and Chair, Life Sciences Talent Initiative Academic Task Force

2. Partnering for Prosperity: Encouraging Collaboration between Industry & Academia to Meet the Demand for Workers

Co-chairs:

- Representative Michael J. Rodrigues, House Chair, Legislative Biotechnology Caucus and House Chair of Joint Committee on Consumer Protection and Professional Licensure
- Dr. Carole Cowan, President, Middlesex Community College

Panelists:

- Lance Hartford, Executive Director, Massachusetts Biotechnology Education Foundation
- Veronica Porter, Ph.D, Assistant Professor and Coordinator of Cooperative Education, College of Arts and Sciences, Northeastern University
- Michelle Keech, Associate Director, Talent Acquisition, Pharmaceutical Operations and Technology, Biogen Idec

Panel Moderator:

- Joan Wood, Senior Vice President of Leadership & Organization Development, Genzyme

3. Attracting and Retaining a Life Sciences Workforce: Addressing Quality/Cost of Living and Other Key Employee Issues

Chair:

- Tina Brooks, Undersecretary, Mass Department of Housing & Community Development

Panelists:

- David McLaughlin, Executive Director, Boston World Partnerships and former Director of Marketing at the Boston Redevelopment Authority
- John Hennessy, Executive Director and General Manager, AstraZeneca R & D Boston
- Dr. Eileen Habelow, Regional Director and Vice President, Randstad

Panel Moderator:

- Glen Comiso, Director of Life Sciences & Health, Massachusetts Technology Collaborative/Massachusetts Life Sciences Collaborative

4: Regional Needs and Advantages—Developing a Statewide Strategy to Sustain the Life Sciences Workforce

Co-chairs:

- Representative David Torrisi, House Chair, Joint Committee Labor and Workforce Development
- Jennifer James, Undersecretary of Workforce Development, Massachusetts Department of Workforce Development

Panelists:

- Kevin O'Sullivan, President & CEO, Massachusetts Biomedical Initiatives
- Dr. Steven Richter, President & CEO, Microtest Inc.
- Karin Gilman, General Manager, Symmetry Medical/TNCO and Chair of MassMEDIC
- Chris Perley, Managing Director, Wyeth Biotech Andover

Panel Moderator:

- Chris Gabrieli, Managing Partner, Bessemer Venture Partners

12:30 pm **Luncheon with the Honorable Deval Patrick, Governor, Commonwealth of Massachusetts**

1:45 pm **Afternoon Plenary Session: Report of Breakout Groups**

Panel of Responders:

- Daniel O'Connell, Secretary, Executive Office of Housing and Economic Development
- Suzanne M. Bump, Secretary, Executive Office of Labor and Workforce Development
- Representative Michael J. Rodrigues, House Chair, Legislative Biotechnology Caucus and House Chair of Joint Committee on Consumer Protection and Professional Licensure
- John Hennessy, Executive Director and General Manager, AstraZeneca R&D Boston
- Dr. Patricia Plummer, Chancellor, Massachusetts Board of Higher Education
- Dr. Jack Wilson, President, University of Massachusetts

3:00 pm **Adjourn**

LSTI Summit Attendees

Name		Title	Organization
Peter	Abair	Director for Economic Development	Massachusetts Biotechnology Council
Leslie	Ackles	Director, Organizational Development & Training	UMass Donahue Institute
Mitchell	Adams	Executive Director	Massachusetts Technology Collaborative
Douglas	Allen		Salem State College
Joseph	Alviani	Life Sciences Consultant	Alviani & Associates
Jillian	Anderson	Employer Relations Coordinator	Worcester State College
Richard	Antonak	Vice Provost for Research	UMass Boston
Peter	Antonellis	Legislative Aide	Office of Chairman Michael Rodrigues
Michelle	Auerbach	Asst. Vice Provost for Research	UMass Boston
Robyn	Avery	Sr. Research Recruiter	Children's Hospital Boston
Shahira	Badran	Assistant Professor & Biotech Program Coordinator	Bunker Hill Community College
Anne-Marie	Baker	Industrial Liaison	UMass Lowell's Medical Device Development Center (M2D2)
Daron	Barnard	Assistant Professor, Biology	Worcester State College
Abi	Barrow	Director, Mass Technology Transfer Center	University of Massachusetts
Ted	Bauer	Machining Project Coordinator	Mass Manufacturing Extension Partnership
Karen	Bean	Associate Director, Office of Community Programs	UMass Boston
Edmund	Beard	Senior Advisor	UMass President's Office
Joanne	Beck	Plant Manager	Abbott Bioresearch Center
Joan	Becker	Associate Vice Provost	UMass Boston
Richard	Beckwitt	Professor	Framingham State College
Eunice	Bellinger		MassBay Community College
Ellen	Bemben	President	Regional Technology Corporation
Milton	Benjamin	President and CEO	Initiative for a New Economy
Anthony	Bent	Superintendent of Schools	Shrewsbury Public Schools
Edward	Berger	Principal	Larchmont Strategic Advisors
Dennis	Berkey	President	Worcester Polytechnic Institute
Arthur	Bernard	Vice Chancellor for Government Relations and Public Affairs	UMass Boston
Carole	Berotte-Joseph	President	Mass Bay Community College
Frederic	Bertley		The Franklin Institute/Roxbury Community College
Detlev	Biniszkiewicz	Head of Strategy	Novartis
Paul	Bleicher, MD	Founder & Chairman	Phase Forward Inc
Joshua	Boger	Founder, President & Chief Executive Officer	Vertex Pharmaceuticals
Deborah	Boisvert	Director, BATEC Center for IT	UMass Boston
William	Brah	Asst. Vice Provost for Research and Exec. Dir, Venture Development Center	UMass Boston
Jeff	Brancato	Associate Vice President for Economic Development	University of Massachusetts
Tina	Brooks	Undersecretary	Mass Department of Housing & Community Development
Cosabeth	Bullock	Account Coordinator	Solomon McCown

Suzanne	Bump	Secretary	Mass Office of Labor & Workforce Development
John	Burand	Associate Professor	UMass Amherst
Joseph	Capuano	Deputy Chief of Staff	Executive Office of Housing & Economic Development
Ted	Carr	Chief of Staff	Executive Office of Housing and Economic Development
Anthony	Carruthers	Professor and Dean of the Graduate School of Biomedical Sciences	UMass Medical School
Tracy	Chandler	Staffing Lead	Vertex Pharmaceuticals
Brendan	Chisholm	Director of Health Science Initiatives	UMass Medical School
Thomas	Chmura	Vice President for Economic Development	UMass Office of the President
Partha	Chowdhury	Interim Vice Provost for Research	UMass Lowell
John	Ciccarelli	Assistant to the Chancellor for Economic Development	UMass Boston
April	Cloutier	Director of Operations	Regional Technology Corp (RTC)
Mark	Cohen	Director of Human Resources	Broad Institute
Dr. Timothy	Coleman	Manager	PricewaterhouseCoopers LLP
Michael	Collins, M.D.	Sr. VP for the Health Sciences and Interim Chancellor	UMass Medical School
Glen	Comiso	Director of Life Sciences & Health	Mass Technology Collaborative/Mass Life Sciences Collaborative
Elizabeth	Connor	Associate Professor	UMass Amherst
Carole	Cowan	President	Middlesex Community College
Amy	Crawford	Director of Human Resources	Infraredx
Guy	Crosby	Associate Professor	Framingham State College
Zoltan	Csimma	Senior Vice President & Chief Human Resources Officer	Genzyme
Robert	Curtis	CEO	Regional Technology Development Corporation
Susan	Daudelin	Director of Industry Relations, Venture Development Center	UMass Boston
Junior	Delgado	Assistant Director - Career Center	Westfield State College
Daniel	DeSantis		
Libby	DeVecchi	Communications Director	UMass President's Office
Alan	Dittrich	President	Massachusetts Society for Medical Research
Gerard	Doherty	Attorney	Law Offices of Gerard F. Doherty
Kay	Doyle	Professor/Chairperson	UMass Lowell
Susan	Dutch	Associate Dean/Administrative Fellow	Westfield State College
Marcia	Eagleson	Director of Career Services	Worcester State College
Yossi	Elaz	Medical Devices Professional	Consultant
Sharon	Faherty	Project Manager	UMass Donahue Institute
Elizabeth	Finn-Elder	Vice President	Sallop Insurance Agency
Jack	Fitzmaurice	Staffing Director	Wyeth Biotec
Stephen	Flavin	Dean, Corporate & Professional Education	Worcester Polytechnic Institute
David	Fleming	Group Senior Vice President	Genzyme Corporation
Terence	Flotte	Dean and Executive Deputy Chancellor	UMass Medical School
Maureen	Flynn	Special Counsel	Executive Office of Housing & Economic Development

Paul	Friedmann	Executive Director	Pioneer Valley Life Sciences Institute
Ellen	Fynan	Professor and Interim Chair, Dept. of Biology	Worcester State College
Christopher	Gabrieli	Managing Partner	Bessemer Venture Partners
Mark	Garfinkel		Boston Herald
Karen	Gilman	General Manager	Symmetry Medical/TNCO & Chair, MassMEDIC
Greer	Glazer	Dean & Professor of Nursing	UMass Boston
Eileen	Glovsky	Deputy Treasurer	Office of the State Treasurer
Lori	Gold	Director of Membership & Business Development	Mass Biotech Council
Terrence A.	Gomes	President	Roxbury Community College
Robert	Goodhue	Executive Director of Corporate Relations	UMass President's Office
Michael	Goodman	Director of Economic & Public Policy Research	UMass Donahue Institute
Steve	Goodwin	Dean, College of Natural Resources & the Environment	UMass Amherst
Leah	Gourley	Senior Account Executive	Solomon McCown
Carol	Grady	VP	JVS
Mary	Grant	President	Massachusetts College of Liberal Arts
Martha	Gray	Director	MIT/Harvard HST
J.	Griesemer	Executive Director	UMass Donahue Institute
Suzanne	Grillo	Website Marketing Coordinator	MassBioEd Foundation
Andrew	Grosovsky	Dean	UMass Boston
Sharon	Grundel	Manager, Workforce Development	UMass Medical School
Ronnie	Haas	Facilitator & Curriculum Designer	UMass Donahue Institute
Eileen	Habelow	Regional Director & Vice President	Randstad, USA
Lorna	Hamel	Executive Assistant to Steve Richter	Microtest Inc.
Lance	Hartford	Executive Director	Mass Biotechnology Education Foundation
Kate	Hayes	Consultant	
Jack	Healy	Director of Operations	Mass Manufacturing Extension Partnership
John	Heffernan	Vice President, Policy & External Affairs	Massachusetts Biotechnology Council
Eric	Heller	Director, Research & Evaluation	UMass Donahue Institute
John	Hennessy	Executive Director & General Manager	AsstraZeneca R & D
Brandynn	Holgate	Doctoral Candidate	John W. McCormack Graduate School of Policy Studies
Michael	Hunter	Director, Business Resource Team	Mass Office of Business Development
Michael	Imhoff		Independent Consultant
Andrew	Imrie	Operations Manager	Randstad RCS
Bruce	Jackson	Professor and Chair, Department of Science	Massachusetts Bay Community College
Jennifer	James	Undersecretary	Mass Department of Workforce Development
Deborah	Jancourtz	Asst. Graduate Coop Coordinator	Northeastern University
Mark	Jewell	Business Writer	Associated Press
Julie	Joncas	Administrative Director, CCM	Massachusetts General Hospital
Graham	Jones		Northeastern University
Kofi	Jones	Director of Communications	Mass Office of Housing & Economic Development

Whitney	Jones	Research Associate	UMass Medical School - Commonwealth Medicine
Gladymir	Joseph	Student	Shadowing Linnea Walsh
Monica	Joslin	Dean of Academic Affairs	Massachusetts College of Liberal Arts
Charles	Kaminski	Asst. Dean of Academic Affairs	Berkshire Community College
Christine	Karavites	Senior Consultant	UMass Donahue Institute
Michelle	Keech	Associate Director, Talent Acquisition Pharmaceutical Operations & Technology	Biogen Idec
Catherine	Kendrick	Executive Director, Distance Market Development and Corporate Outreach	UMass Lowell
Annamarie	Kersten	Regional Director, Greater Boston	Mass Office of Business Development
Paul	Key	District Manager	Randstad USA
Tala	Khudairi	Dean, Math, Science & Technology	Roxbury Community College
William E.	Kiernan	Research Professor & Director, Institute for Community Inclusion	UMass Boston
Ranch C.	Kimball	President and CEO	Joslin Diabetes Center
Amanda	Kirk	Project Assistant, College of Natural Sciences & Math	UMass Amherst
Jessie	Klein	Associate Dean Mathematics and Sciences	Middlesex Community College
Deborah	Kochevar	Dean	Cummings School of Veterinary Medicine at Tufts University
Jeanette	Kohlbrenner	Director, Human Resources	Infinity Pharmaceuticals
Jack	Kowalski		Ex Office of Housing & Ec Development
Donna	Kuizenga	Dean, College of Liberal Arts	UMass Boston
Michael	Laffin	Director, Learning & Organizational Development	EMD Serono
George	Langford	Dean, College of Natural Sciences & Mathematics	University of Massachusetts Amherst
Winston	Langley	Associate Chancellor	UMass Boston
Carl	Lawton	Director	Massachusetts Biomanufacturing Center
Karen	Lawton	Director of Admissions	UMass Medical School
Robert	Layne	Director, Outreach Programs	UMass Medical School
William	Lazonick	Professor	UMass Lowell
Todd	Leach	Senior Associate Dean	Northeastern University
Todd	Lee	Senior Planner	Office of Jobs and Community Services, City of Boston
Ken	Lemanski	Executive Office	Council of Presidents, Mass State Colleges
Darrell	LeMar	Deputy Director of Communications	Executive Office of Housing & Economic Development
Mark	Leuchtenberger	President & Chief Executive Officer	Targanta Therapeutics
Rachael	Liebert	Press Aide	Executive Office of Housing & Economic Development
Leo	Liu, MD	Founder, President & CEO	Cambria Biosciences
Linda	Looft	Assistant VP, Government & Community Relations	WPI
Lauren	Louison	Senior Vice President	Solomon McCown
Becky	Loveland	Research Manager	UMass Donahue Institute
Alan	Macdonald	Executive Director	Massachusetts Business Roundtable
Richard	Maguire	Director of Human Resources	UMass Medical School

Jane	Markarian	Special Projects & Outreach Manager, College of Natural Sciences & Mathematics	UMass Amherst
Erin	Mawn	Project Coordinator for Workforce Development Initiatives	Massachusetts Board of Higher Education
Sandra	Mayrand	Director, Regional Science Resource Center	UMass Medical School
Susan	McAndrew	Fiscal Assistant	UMass Donahue Institute
Stephen	McCarthy		UMass Lowell
Christine	McConville		Boston Herald
Thomas	McCullough	Director, Corporate and Foundation Relations	UMass Medical School
Stephanie	McCune	Human Resource Manager	Becton Dickinson (BD) Ophthalmic Systems
Bill	McDermott	Attorney	McDermott, Quilty & Miller
David	McDermott		UMass President's Office
David	McDonough	Director of Career Services	Clark University
David	McLaughlin	Executive Director	Boston World Partnerships
Barbara	McNulty	Massachusetts Technology Transfer Center	University of Massachusetts
Lee	Merrill	VP, Human Resources	Targanta Therapeutics
Marla	Michel	Director, Research Liaison & Development	UMass Amherst
Melissa	Milani	Learning & Development Consultant	PAREXEL International
David	Miller	Business Development Director	Pioneer Valley Life Sciences Institute
Marshall	Milner	Exec. Dir., Science Training Programs	UMass Boston
Kate	Modzelewski	Research Analyst	UMass Donahue Institute
Fatemeh	Mojtabai	President & Chief Scientific Officer	Novatarg Pharmaceuticals, Inc.
Celia	Moore	Professor and Chair of Psychology Dept.	University of Massachusetts Boston
Hadley	Moore	Graduate Research Assistant	UMass Donahue Institute
Paul	Morrison	Economic Development Associate	Brockton 21st Century Corporation
J. Keith	Motley	Chancellor	University of Massachusetts Boston
Janice	Motta	Executive Director	Massachusetts Community Colleges
Susan	Moulton	President	Moulton Consulting
TJ	Mountziaris	Professor and Head	Chemical Engineering and UMass NanoMedicine Institute
John E.	Murphy, Jr.	Counsellor at Law	Issues Management Group
Eric	Nakajima	Senior Policy Advisor	Executive Office of Housing & Economic Development
Imran	Nasralluh	Chief Business Officer	Massachusetts Biotechnology Council
Judith	Ockene	Interim Vice Chancellor of Faculty Affairs	UMass Medical School
Daniel	O'Connell	Secretary	Mass Office of Housing & Economic Development
Robert	O'Leary	Senate Chair	Joint Committee on Higher Education
Kevin	O'Sullivan	President & CEO	Massachusetts Biomedical Initiatives
Eric	Overstrom	Director, Life Sciences	Worcester Polytechnic Institute
Ezat	Parnia	Provost/Executive Vice President	Nichols College
Shana	Passonno	Program Manager, Institute for Cellular Engineering	UMass Amherst
Deval	Patrick	Governor	Commonwealth of Massachusetts
Chris	Perley	Managing Director	Wyeth Biotech

Lou	Petrovic	Assistant Vice Chancellor Research Development	UMass Dartmouth
Alex	Philippidis	Editor	BioRegion News
Constance	Phillips	Director	CityLab Academy - Boston University
Leslie	Pippin	Staffing Lead	Vertex Pharmaceuticals
Patricia	Plummer	Chancellor	Massachusetts Board of Higher Education
Veronica	Porter	Asst Professor & Coordinator of Cooperative Education	Northeastern University
Janice	Raftery	Staff Assistant	UMass Donahue Institute
George	Ramirez	General Counsel	Executive Office of Housing & Economic Development
Zoe	Ramos	Program Administrator	UMass Amherst
Lisa	Rapp	Chair, Biotechnology Program	Springfield Technical Community College
Paul	Raverta	President	Berkshire Community College
Mel	Reed	Senior Agent	Randstad USA
Joan	Reede	Dean for Diversity and Community Partnership	Harvard Medical School
Steven	Richter	President & CEO	Microtest Inc.
Michael	Rodrigues	House Chair	Legislative Biotechnology Caucus
William	Rosenberg	Executive Director Commerical Ventures & Intellectual Property	UMass President's Office
David	Ross	Director of Human Resources	Avecia Biotechnology Inc.
Robert	Ross	BioTeach Program Manager	MassBioEd Foundation
Michelle	Salas	Sr. Staffing Specialist	Millennium Pharmaceuticals
Linda	Sallop	President	Sallop Insurance Agency
Sarmad	Saman	Interim Dean-STEM Division	MassBay Community College
Jeffrey	Sanchez	MA State Representative	Commonwealth of MA
John	Sauers	Training Manager	Abbott Bioresearch Center
Steve	Schiavo	Manager, Human Resources	Vertex Pharmaceuticals
Frank	Schickor	Asst Professor of Biology	Berkshire Community College
Russell	Schutt	Professor of Sociology	UMass Boston
Sanchita	Sengupta	HR Generalist	Children's Hospital Boston
Maureen	Shamgochian	Associate Vice President for Academic Affairs	Worcester State College
Elena	Sharnoff		UMass Amherst
Greg	Sheldon	President	Sheldon Collaborative, Inc.
Phillip	Sheppard	Assistant to the President	Massasoit Community College
Robin	Sherman	Project Manager	UMass Donahue Institute
Bal Ram	Singh	Prof, Chemistry & Biochemistry	UMass Dartmouth
Navjeet	Singh	VP Research and Evaluation	Commonwealth Corporation
Lisa	Smith		UMass President's Office
Lesley	Smythe	Senior Program Manager	UMass Donahue Institute
Nancy	Snyder	President/CEO	Commonwealth Corporation
Sophan	Sok	Career Coach	Boston Private Industry Council/CityLab Academy
Helene	Solomon	President	Solomon McCown
Thomas	Sommer	President	MassMEDIC
Amy	Sprenkle		Salem State College
Marie	St. Fleur	State Representative	Commonwealth of Massachusetts
Ann	Stanesa	Associate Director	Genzyme

Jim	Stanton	Director, The Technology Initiative	Metro S/W REB
Rebecca	Starcevic	Associate Director of Communications	UMass President's Office
Sheila	Sullivan-Jardim	Executive Director	Brockton Area Workforce Investment Board
Jean	Supel	Research Manager	UMass Donahue Institute
Jordan	Swift	Cooperative Education Coordinator	Northeastern University
Andrea	Swirka	Associate Director, Corporate Outreach and Special Programs	Salem State College
Jim	Terlizzi	Program Coordinator	Collaborative Project for Math, Science and Interdisciplinary Education
Jeremy	Thompson	Research Assistant	Boston Redevelopment Authority
Kevin	Thurston	Executive Director	MetroWest STEM Education Network
Greta	Tinay	Life Sciences Analyst	Massachusetts Technology Collaborative
E. Teresa	Touey		Lumena Consulting, LLC
Carole	Traeber	Consultant	Compass Consulting Group
Marie	Tremblay	Talent Acquisition	Medtronic
Mark	Trusheim	President	Co-Bio Consulting, LLC
Michael	Tutty	Director Academic Services,Center for Health Policy and Research	UMass Medical School
Paul	Vigeant	Assistant Chancellor for Economic Development	UMass Dartmouth
Sanjeeve	Wadhani	Project Management Consultant	IPM INC.
Dave	Wallace	Director of Apprenticeship Training	Commonwealth of Massachusetts
Todd	Wallack	Reporter	Boston Globe
Linnea	Walsh	Director of Communications	Ex Office of Labor & Workforce Development
Melissa	Walsh	Chief of Staff	Massachusetts Life Sciences Center
Tracy	Ware	Professor of Biology	Salem State College
Bill	Warmack	Business Rep.	Dept. Workforce Development
Deanna	Warner	Lecturer	Salem State College
Miwa A	Watkins	Human Resources	Cambridge Consultants
Charles	Weitze	Dean of Math & Science	Mt Wachusett Community College
Christine	Williams	Policy Advisor	Executive Office of Housing & Economic Development
Barbara	Willwerth	Director, Human Resources	Innovative Spinal Technologies
Jack	Wilson	President	University of Massachusetts
John	Witt	Program Manager	Just-A-Start Corporation
Kristin	Wobbe	Associate Professor and Interim Head	Worcester Polytechnic Institute
Joan	Wood	Senior Vice President of Leadership & Organization Development	Genzyme
Judith	Woolfson	Faculty Coordinator, Cooperative Education	Northeastern University
Xylina	Wu	Dir of Business Development	Massachusetts International Office of Trade & Investment
Rachel	Yamartino	Program Manager	Worcester Polytechnic Institute
Mary Ellen	Yates	Director of Corporate Relations	UMass President's Office
Linda	Young	Dean of Mathematics and Sciences	Middlesex Community College
Hannah	Yun	Coordinator, Education & Training Programs	Massachusetts Biotechnology Education Foundation
Isa	Zimmerman	Senior Fellow, STEM Initiative	University of Massachusetts