People Putting Cells to Work or Cells Putting People To Work?

A Case Study of Biotechnology & Employment in Massachusetts

By

Thomas Coykendall Webb

Submitted to the Department of
Urban Studies and Planning
in Partial Fulfillment of the
Requirements for the
Degree of

MASTER OF CITY PLANNING

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 1991

Signature of Author _____
Department of Urban Studies and Planning
May 16, 1991

Certified by _____
Christopher Tilly
Visiting Assistant Professor, Urban Studies & Planning

Accepted by _____
Philip Clay
Chair, Master of City Planning Committee

People Putting Cells to Work or Cells Putting People to Work?

A Case Study of Biotechnology & Employment in Massachusetts

BY
THOMAS COYKENDALL WEBB

Submitted to the Department of Urban Studies and Planning on May 16, 1991 in partial fulfillment of the requirements for the Degree of Master of City Planning

ABSTRACT

An analysis of low- and semi-skill labor in biotechnology manufacturing was done using case studies of eleven Massachusetts biotechnology firms. Four major questions were asked: 1) How are production jobs generated in biotechnology at different stages of product development? 2) What are the skill requirements for manufacturing jobs? 3) How are women and people of color represented in manufacturing occupations? 4) How good are biotech manufacturing jobs from the standpoints of compensation, opportunities for advancement, and worker safety?

The results show that total job growth is modest by comparison with computers, and that a growth spurt occurs between product testing and commercial license. Skill requirements are significantly lower in commercial plants than in pilot plants. Women are represented in laboratory and management occupations (with the exception of senior administrative occupations) at similar levels to national averages, but people of color are underrepresented. Biotech manufacturing jobs pay less than the average production wage for all Massachusetts manufacturing industries. Opportunities for advancement are more limited than traditional manufacturing industries. Workers may be exposed to a number of biohazards, but the industry generally takes strong measures to prevent injury.

The findings illustrate the important differences in employment outcomes among high tech industries (including biotech), and among biotech market sectors. They also help point out important employment issues in the emerging biotech industry, such as increased skill requirements for entry-level jobs, difficulty of access especially for people of color, and the limitations to job advancement for non-degreed workers. These are issues with which communities and state government must grapple as they struggle to keep their economies competitive, promote jobs that serve local residents well, and enhance opportunities for underserved populations.

Thesis Supervisor: Christopher Tilly, Visiting Professor

ACKNOWLEDGEMENTS

Several people deserve special thanks for helping see me through this project. The first person who must be thanked is my Advisor, Chris Tilly. There were many times I began meetings with Chris feeling anxious about my thesis, but I never left feeling anxious after meeting with him. He provided excellent guidance, and helped make the project fun.

I also wish to thank the two organizations which helped to sponsor this research: The Massachusetts Centers of Excellence (MCEC), and the Research and Policy Department at the Boston Redevelopment Authority (BRA). In particular, Fernando Quezada, MCEC, provided invaluable contacts with local biotechnology firms. John Avault and Mark Johnson, BRA, provided three equally valuable resources: office space, technical support, and good humor.

Special thanks goes to the companies, and consultants who participated in the study. The representatives with whom I met were extremely cooperative and fascinating people. I hope they can learn from this report too. My friend, Tina, generously gave her time to prepare the tables included in the thesis.

Finally, I wish to thank my parents who, although not be able to share in my graduation, are a source of everlasting love to me.

TABLE OF CONTENTS

Chapter 4: Skill Requirements

Chapter 5: Women & People of Color

Chapter 6: Job Quality

Chapter 7: Conclusions & Recommendations

Chapter 1
Introduction

Rarely has a new technology generated as much hope and controversy at the same time as biotechnology has. One reason for hope is that biotechnology will make great improvements in human health. However, many state leaders are excited about biotechnology because of its promise to bring economic growth, especially employment. The following research examines the employment characteristics of manufacturing in Massachusetts biotech companies to see how large and widespread the employment potential of biotech really is.

What follows are the results and analysis of a study of the employment benefits to low- and semi-skilled labor in biotechnology. The focus is on low- and semi-skilled workers because they represent the largest segment of the workforce, and they have suffered from recent changes in the availability and quality of work during the last several decades. We need to better understand the implications of new technologies and industries, like biotechnology, for this segment of the labor force.

Before summarizing the research questions and results, a short definition of biotech is provided, along with a brief discussion of some of the larger and controversial issues surrounding biotech. The controversies arise because certain biotech applications pose serious ethical and environmental dilemmas. These issues should not be entirely overlooked when one is considering how to support the industry to enhance employment, and other benefits.

WHAT IS BIOTECHNOLOGY?

People have been putting cells to work for centuries. Whenever we make beer or bread, we harness the productive capabilities of yeast, and in a sense, are practicing biotechnology. However, our understanding of plant and animal cells reached a critical turning point in 1953, when Watson and Crick discovered the structure of DNA (deoxyribonucleic acid), the molecule that carries the genetic information governing the growth, maintenance, and reproduction of most living systems. This knowledge helped scientists to understand how proteins (molecules composed of amino acids), and other naturally occurring substances in the cell, can be used to treat and even prevent disease.

Biotechnology is the collection of techniques that use naturally occurring substances and life processes to produce a wide range of products and services for applications in human health, animal health, and agriculture. The best known of these techniques is called gene splicing (or recombinant DNA), because it allows for the combination of segments of DNA from different organisms. Microbes into which genes have been spliced may be commercially valuable because they can produce useful proteins in larger and purer quantities than can be obtained economically from other sources.

Perhaps the most successful example of a product obtained through genetic engineering is human insulin. Prior to human insulin, the only other sources of insulin for diabetic patients were pigs and cows. However, some people were allergic to the insulin taken from these animals. When scientists first managed to get genetically engineered bacteria to grow human insulin in a test tube in 1978, biotechnology achieved its first major victory.

CONTROVERSY

Biotechnology is beginning, and may continue to have a large, positive impact on human health care in terms of diagnosing, curing, and even preventing disease. While other technologies have had significant affects on the quality of human life, none has come so close to controlling the biological basis of life itself. Because of its power, there are many debates over how to use the technology, and how to eliminate or minimize its potential dangers.

Since the beginning, a number of controversies have surrounded biotechnology. Some of these controversies are ethical in nature, while others are ecological. An example of an ethical issue in biotechnology occurs in diagnosis. Biotechnology has enabled more precise diagnosis of certain diseases based on the presence or absence of a certain gene, which is associated with the disease. For example, should a person be told she has the disease if there is no known cure, especially if it is not certain whether she will develop it? Can society protect that same individual from possible discrimination (e.g. by insurance companies)?

Another set of controversies having to do with biotechnology involve the environment. Microbiologists and ecologists continue to debate how to measure and manage the risk of an accidental (or deliberate) release of genetically engineered microbes into the environment.

Microbiologists say the risk is too small to measure and therefore insignificant, while ecologists argue that the effects of releasing genetically engineered microbes into the environment should be fully explored before it occurs. These and other issues will continue to be debated, and must not be separated from public considerations of how to support biotechnology.

BIOTECHNOLOGY AND ECONOMIC DEVELOPMENT

Economists and planners are also interested in biotechnology, because they associate it with other high tech industries, which have bolstered the US economy and employed lots of people during a time when many traditional industries were in decline. During the mid-80s, industry forecasters predicted that the biotech industry would reach $100 billion in revenues by the turn of the century. While this estimate may turn out to be overly optimistic, it nonetheless caused many states to develop strategies to capture the economic and employment benefits associated with biotech. Biotechnology represents a major technological innovation that will give US companies an advantage over competitors in the world economy. Competitive companies are expected to grow fast and employ lots of people.

Biotechnology is especially important to Massachusetts because the state has the nation's third highest number of biotechnology firms. Estimates of total 1990 annual revenues for these firms ranges between $263 million (Ernst & Young, 1990, p.89) and $1.3 billion (Feinstein, 1990). Federal research dollars help fuel the science on which the industry is based, and Massachusetts medical research institutions and universities get a large share. Local receipts of federal funding rose from $317 million in 1981 to $503 in 1988 (Boston Redevelopment Authority, "Outlook for the Nineties," 1990).

Biotech is also important because the state's economy is presently experiencing a severe slowdown. Unemployment in Massachusetts averaged nearly 9.0% during the first quarter of 1991, nearly double the rate of the previous year and higher than the national average. Due to its promise and good timing, biotech is attracting special attention from political leaders and the media. Local leaders have encouraged the hope that biotechnology will save the state's faltering economy. In a 1990 discussion paper, outgoing governor, Michael Dukakis, wrote that,

> *Massachusetts needs a new engine -- an industry, or several, that hold promise of rapid growth in manufacturing as well as R&D, and which have the power to spin off many times their weight in derivative jobs... Massachusetts should be a world center of biotechnology, biomedicine, and related industries. We should be a leader in manufacturing as well as research. And that is our goal.* [1]

Assumptions about job growth were reiterated more recently by Dr. James M. Howell, consultant and former chief economist of the Bank of Boston. He argued that the Massachusetts, and especially Boston economy has become a knowledge-based economy in which young, high-technology firms are the engines of future growth. He counts biotechnology among the high-technology firms.

> *As these firms are created, the achievement of high and rising levels of productivity, the continuous upgrading of product design and quality and the aggressive pursuit of new market segments will be quickly translated into new jobs and higher incomes for residents of the city and state.*[2]

RESEARCH FINDINGS

While it appears to be true that biotech firms are creating new jobs and paying high salaries to their workers, on average, the implicit assumption is that biotech will be like computers and generate lots of jobs and help the economy rebound. The following research finds that job growth will actually be quite modest relative to computers, and that the average wage for non-degreed production workers in Massachusetts biotech is less than the average for all manufacturing industries in the state.

The majority of the Massachusetts workforce does not qualify for biotech jobs at present, because they do not have the level of education required by firms. Most biotech jobs require a bachelor's degree, which most Massachusetts workers do not have. However, jobs in production operations in mature biotech companies typically require only a high school or associate's degree.

---

[1] "Winning the Nineties: Economic Strategy for Massachusetts." Prepared for the Governor's Economic Summit, January 19, 1990, at MIT. pp. 8-9.

[2] See Boston Redevelopment Authority "The Howell Report," November, 1990. p.16.

Education is not the only barrier to job access. The current biotech workforce tends to be more homogenous than the total workforce for all industries. People of color are virtually absent from the laboratories, and are represented in very small numbers in production areas of most biotech firms (greatly varying from firm to firm). Women are present in biotech laboratories in larger proportions than other high tech industries, but are underrepresented in senior management occupations.

Biotech is a new and unique industry. There are important differences among biotech firms as well as between biotech and other high tech industries. In general, many of the comparisons made between biotech and other high tech industries, in terms of employment, are simply not true. States investing public money and hope in biotech may be sadly disappointed. While biotech is a growth industry which will lead to certain public benefits, it has special characteristics and needs that must be understood by those who wish to enhance the benefits by supporting the industry. States (and cities and towns) must understand those characteristics in order to effectively plan for biotech economic development.

Thesis Organization

I provide an overview of the research approach in chapter 2. It sets the context for the study, introduces the research questions, reviews relevant literature, and describes the methodology used. The research questions cover three, broad areas of employment: job creation, access, and quality. Chapter 3 presents the results of my research on job creation. Chapter 4 deals exclusively with job access from the standpoint of skills, while chapter 5 takes up the question job access as it pertains to women and people of color. Finally, in chapter 6, I present the results on job quality, including wages and benefits, opportunities for advancement, and worker safety.

Each chapter analysizes the findings from the standpoint of low- and semi-skilled labor. This analysis sets the stage for the final chapter, which pulls together the broad themes of the research, and identifies several policy opportunities to promote and enhance employment benefits for Massachusetts residents.

Chapter 2

Research Overview

INTRODUCTION: THE NEW ECONOMY & EMPLOYMENT

The most recent thinking about economic development and employment usually begins from the premise that American industries have lost their competitive edge (Harrison & Bluestone 1982, Reich 1987, Osborne 1988, Blakely 1989). While the particular trends and causes of America's current economic woes are widely debated, there is agreement that the world economic system today includes many new strong competitors from Asia and Europe who have cut into the profit margins of US corporations.

This new competition particularly hurt American corporations during the 1960s and 1970s. Firms restructured in response to the profit squeeze. Their strategies to cut costs and regain profitability included measures to shed jobs, reduce wages, and relocate production off shore (Harrison & Bluestone 1982, 1988). While the bad news is that we continue to lose manufacturing jobs, the good news is that other sectors of the economy are adding jobs. However, many new jobs in the service sector (e.g. food services and retail) do not pay as well as manufacturing jobs, and sometimes do not provide full health coverage.

Two of the major outcomes of corporate and economic restructuring for labor have been decreasing real wages and growing income inequality (Harrison & Bluestone 1988). As a result, many Americans are struggling harder (and sometimes failing) to maintain the same standard of living enjoyed by their parents. At the same time, the economy seems to be producing two kinds of jobs: high pay for professional jobs and low pay for low skill jobs especially in the service sector (Harrison & Bluestone, 1982). Therefore, economic development strategies must not only consider job creation, but quality and equity to try and offset the growing inequality (see Schramm, in Bruyn & Meehan, 1987).

High Tech Solutions: Employment for Whom?

Among the solutions being debated, including flexible production and education reform, efforts at the state level have focused on targeting key industries, especially those in

the areas of high technology.[1] The most recent industry to be targeted for state support has been biotechnology, which uses biological processes and substances to produce goods and services (for a list of biotech products, see table 2.1). In its 1988 report, the Office of Technology Assessment counts 33 states with specific funding allocations for biotechnology.[2] The importance of biotechnology in state economic development strategies was likewise observed by researchers at the University of California, Berkeley in a national survey (Blakely, 1988). One of the states banking heavily on biotechnology is Massachusetts.

There are two expectations typically associated with high tech strategies. One is that high tech firms are innovative and competitive and will therefore help stimulate economic revival for regions that host them (Osborne, 1989). The second is that these firms will produce lots of new jobs (Birch 1979). The UCBerkeley survey of state biotechnology policies confirmed the existence of this second expectation. Creating 'skilled-jobs' topped the list of policy objectives of supporting biotech.[3]

However, there is an important distinction between research and development (R&D) and manufacturing. Typically, we expect R&D to employ mostly high-skilled workers, while manufacturing employs more low- and semi-skilled workers. If states are concerned with creating jobs, we would expect them to target manufacturing as one of their top policy goals. However, supporting biotech manufacturing, as opposed to R&D, was at the bottom of the list of policy objectives in the Berkeley survey. Nearly one quarter of the respondents claimed that biotech manufacturing (again, as opposed to R&D) is 'not very important' or 'not important at all.'

It strikes me that states have their priorities reversed. Biotech R&D will generate fewer jobs than manufacturing, and those jobs will not be accessible to low- and semi-skill labor. States should plan for biotech manufacturing if they wish to help non-degreed labor. Enlightened economic development practitioners generally argue that the goals of development

---

[1] There are many definitions of 'high-tech.' I adopt the definition used by Markusen, et. al., in High Tech America, which is to count those industries for whom the proportion of engineers, computer scientists, life scientists, and mathematicians exceeds the manufacturing average.

[2] See OTA (1988), p.55. The count includes support for both academic research and commercial activities.

[3] See Blakely, 1988, "The Search for a New Golden Goose," p.21. The sample includes 37 states.

must go beyond promoting job creation. Employment strategies must also account for job access. Of course, even if you have access, you have to worry about job quality and safety.

RESEARCH QUESTIONS : TARGETING BIOTECH PRODUCTION

Considerable attention has been given to R&D in biotechnology, but less seems to be known about manufacturing. Yet presumably, the largest employment benefits will occur when biotech firms begin manufacturing products for sale, which more and more firms in Massachusetts anticipate doing in the near future.

Answers to employment questions are linked to product life cycle, firm strategies, and location. By developing a set of case studies of biotech firms already engaged in production, I will present information and analysis of four basic questions:

1. How are production jobs generated in biotechnology at different stages of product development?
2. Where will production occur? Within Massachusetts or outside?
3. Who gets these jobs?
    - o How many production jobs are accessible to low- and semi-skilled labor at present?
    - o Will access change in the future?
    - o Do women and minorities have access the production workforce?
4. How good are these jobs?
    - o How do firms compensate production employees?
    - o What are the opportunities for advancement?
    - o Are production jobs safe?

The answers to these questions are important to state policy makers, who must be informed about the employment outcomes of biotech and of opportunities to enhance benefits and upward mobility of low- and semi-skill labor.

LITERATURE REVIEW

There is a substantial body of literature available on economic development and on high technology in the United States. But there is very little written specifically about biotechnology, or especially about its employment implications. However, from the existing literature I have been able to assemble relevant information and predictions for my research questions. I have organized the literature review according to the three employment topics: job growth and location, access, and quality.

Job Growth

I explore job growth by examining three key factors that should predict both growth and variation in production employment. The first is product life cycle. Jobs should be added as the production process matures. The second is market segment. I use the two primary market segments in Massachusetts biotech (therapeutic and diagnostic) to see if there are significant employment differences. The third factor is corporate strategy. Not all firms have growth as their first goal.

Current estimates of total employment in Massachusetts biotech range from 8,000 (Ernst & Young, 1991) to 13,600 (Feinstein, 1990), depending on how biotech is defined. The number of production jobs in the state is estimated to reach 6,300 by 1993 and 25,000 by the year 2000 (Feinstein, 1990). The surveys do not attempt to place these figures in a meaningful context, such as comparing them with employment levels in other industries. Nor do they explain how jobs are created at different stages of product development.

Traditional product cycle theory predicts that employment will be small when a product is in the R&D stage, but increases as new markets are penetrated and as the production process becomes standardized, and finally wanes as markets reach saturation and consumers begin to buy substitutes (Vernon, 1966). However, Michael Storper has criticized product cycle theory for being too rigidly deterministic (Storper 1985). He says the theory abstracts away from the diversity of firms and the importance of historical conditions such as the profit squeeze of the 1970s. Given this critique, employment growth in biotech production should be more difficult to predict.

Besides product life cycle, growth may vary according to market segment. Biotechnology is typically broken into three market segments: therapeutics, diagnostics, and agriculture. A national survey by Ernst & Young suggests that growth in production employment will occur more rapidly with diagnostic products because of the shorter product development which is more than half that of therapeutic products (Ernst & Young, 1987).

In addition to product life cycle and market segment, the number of production jobs in biotech is likely to vary according to firm strategies, which are diverse. Ernst & Young (1990) report five key strategies pursued by companies (see table 2.2). The common goal among large firms is to become a fully integrated company, including developing their own production infrastructure. The top two strategies among small firms are to develop products which can be licensed, and to be acquired by another company. Neither of these strategies is likely to result in big job growth in the near term.

Job Location

Employment benefits from biotech manufacturing will bypass Massachusetts residents if companies carry on production activities outside the state. I will examine the location patterns of R&D and manufacturing among Massachusetts biotech firms. The literature on location is extensive and has gone through several revisions over the last couple of decades, but it provides an interpretative framework for approaching biotech location patterns.

Traditional agglomeration theory predicts that innovation and manufacturing should occur in urban markets to take advantage of external economies, such as lower transportation costs, proximity to suppliers and markets, and labor supply (Richardson 1979). However, since the 1950s, manufacturing operations have moved from core areas to peripheral areas. This pattern has forced a rethinking of the theory.

Product cycle theory predicts that innovation will tend to occur in core urban areas while production will locate in peripheral regions seeking lower production costs as well as access to scattered markets. Dispersion has been aided by reduced transportation costs and improvements in communication technologies. However, increased competition and profit

squeeze have also heightened dispersion as companies moved operations to places where production costs were lower (Harrison & Bluestone 1982).

The literature on high tech location acknowledges that location decisions have changed with the advent of multi-establishment companies (Hymer 1979). In the late 60s, technical, corporate, and administrative activities of high tech companies generally remained in close proximity to one another (Malecki 1980). But since the early 70s, assembly operations have been moved off shore to low wage countries (Glasmeier 1986).

One of the unique dynamics shaping location of production activities in biotech is the tendency of firms to form alliances with larger companies. A study at Berkeley revealed that of 27 collaborations between biotech firms and larger firms, none of the larger firms were in the same state as the biotech firms (Blakely & Nishikawa 1990). Four of those collaborations involved Massachusetts biotech firms, and all every case the partner firms were located in outside Massachusetts -- in Delaware, California, Michigan, and London.

Blakely & Nishikawa reject the agglomeration and product cycle models of biotech location in favor of a model that recognizes that both R&D and production occur concurrently in separate, but allied organizations. They argue the model has three outcomes: 1) alliances will preserve the separate functions of biotech firms (R&D) and their larger partners (production & marketing). 2) Alliances simultaneously divide and bridge R&D from manufacturing and distribution. They divide them in the sense that the activities are carried out by separate entities in different places. They bridge them in the sense that the partnership enables the product to go from R&D to production and marketing through the cooperation of the partners. 3) The tendency for production and marketing jobs to migrate to peripheral areas will largely occur through the existing or expanded labor force of the larger partners, rather than through the biotech firms themselves.

In my research, I will explore the current location patterns of production facilities for Massachusetts firms. While my research will not be an exhaustive look at the many factors involved in location decisions, I hope to identify the trends in thinking among the firms in my case study. In particular, I will describe the location strategies of firms in the state and assess the impact of strategic alliances, looking for variations and patterns among firms.

Job Access

I have two main concerns about job access. The first is to learn what the occupation structure and skill requirements for production jobs are. None of the existing surveys have adequately explored skill requirements. I am particularly concerned to know how many jobs will be available to people with less than a four year degree, and how the skill requirements change as the industry matures. My second concern is to find out the extent to which women and people of color are represented in the production workforce. Again, none of the preceding surveys have attempted to gather this kind of information.

SKILL

How many non-degreed (less than bachelor's) jobs are there in biotech, and are they likely to increase in the future? Product cycle theory predicts that high skill labor is in greatest demand when products are in the innovation stage, and that low skill labor is in greater demand when manufacturing begins. Most people expect skill requirements for jobs in biotech to be high, but it seems unlikely that they will remain high when companies begin manufacturing. Little is known about how occupational structure and skill requirements change as biotech firms become production enterprises.

In the final stages of high tech production, the work involves assembly of component parts, and levels of skill are fairly low (Glasmeier, 1986). Massachusetts high tech industries hired more unskilled workers than the average for all businesses (The High Tech Research Group, 1984). At present, the numbers of non-degreed workers in Massachusetts biotech are quite different. A recent survey estimated that three quarters of Massachusetts biotech jobs require a minimum of four years college for entry-level positions (Massachusetts Board of Regents, 1990). However, I would expect to see these proportions change with time as firms mature and production becomes more routine. Unless production jobs hire employees with less than four years of college, biotech jobs will be beyond the reach of the majority of workers in Massachusetts.

WOMEN & PEOPLE OF COLOR

The composition of the American workforce is changing. Women and people of color represent the fastest growing segments of the workforce. This trend is expected to continue. It underscores the need to design employment policies that are sensitive to demographic changes. Since wage and employment differentials between men and women, and between whites and people of color persist, access to jobs for women and people of color must remain a goal of public policy. Are women and people of color working in occupations in the biotech industry in equal proportion to their employment in similar occupations for all industries? To date, no information on women and people of color in the Massachusetts biotech workforce has been gathered and analyzed.

A 1983 study of biotech in Californian found that women were employed in the total biotech workforce in equal proportion to their employment in all industries, but were heavily overrepresented in clerical occupations (Markusen). Minorities constituted 21% of the biotech workforce. However, Markusen suspected that counting foreign nationals as minorities inflated this percentage. Similar results were found in data on Boston area high technology firms (The High Tech Research Group, 1984). Of particular note was the finding that women represented 57% and 71% of operator and laborer occupations respectively, which was higher than for other industries. Blacks were employed at about one half their rate of employment by other area private employers.

Job Quality

As mentioned above, average real wages have declined since 1973 and service jobs (many of which are low paying and dead end) have outstripped manufacturing jobs (traditionally high paying). Besides wages, job stability has become a concern for many regions who have experienced job loss due to plant relocations. Policy makers have expanded their job goals to include raising job quality. These goals apply equally to biotech job creation strategies.

The distinction between good and bad jobs is open to debate. However, for purposes of my research, I have chosen to investigate wages and benefits, opportunities for

advancement, and worker safety. Little information has been collected about wages paid in biotech production. The average hourly pay for most high tech production workers was found to be less than that of production workers in manufacturing as a whole (High Tech Research Group 1984). Similar comparisons between wages for production workers in biotech and wages for production workers in all Massachusetts manufacturing should be possible.

METHODOLOGY

This section outlines the research hypothesis and explains why a case study approach was used. It goes on to explain the basis on which firms were selected, and describes how several problems were handled in choosing firms. Finally, it reviews the secondary sources used to supplement the case studies.

Hypothesis and General Approach

While biotechnology offers potential long term economic benefits (such as innovation, investment, employment, and taxes), not many production jobs will be created. Most of the employment benefits will accrue to people with high skill. Moreover, jobs will not automatically benefit low-skill labor, women, and people of color. Redistributing employment benefits will require government intervention to enhance opportunities and upward mobility.

Using primary data chiefly taken from surveys and case studies of Massachusetts biotech firms, I will analyze the employment opportunities in production and make policy recommendations. While case studies do not allow generalizations about the entire industry in Massachusetts (nor about the nation), they provide more in depth analysis and qualitative information than can be gained easily through surveys. Furthermore, I have chosen to cover the subject of low- and semi-skill labor in biotech broadly rather than in depth. So inevitably a detailed analysis of individual labor topics will be sacrificed for a presentation of the broader picture.

Selection of Firms

I had assistance in selecting firms from Fernando Quezada of the Massachusetts Centers of Excellence Corporation (MCEC). His knowledge of, and contacts with the industry were invaluable. I used two main criteria in selecting firms for the case studies. The first criteria was to select the firms with large and mature production capacities. This criteria was chosen because I assume we can learn more about biotech production from those with the most experience. Furthermore, we can assume that younger firms in the same industry subsector will probably follow production paths similar to those followed by the most mature firms.

The second criterion for the sample was to have a representative cross-section of each biotech market segment: therapeutic, diagnostic, agriculture, and suppliers. However, in my analysis, I concentrate on therapeutic and diagnostic firms for making comparisons. By one estimate, therapeutic and diagnostic companies comprise 80% of all biotech companies in Massachusetts. These two segments comprise 82% of my sample.

Although my sample of firms was not chosen randomly, it is a representative sample on which to base case studies and draw general conclusions. I used all dedicated biotech firms (or DBFs)[4] in Massachusetts as the population for my sample. The best estimate of that population is 116 firms. My sample included 11 cases (see table 2.3) which is just 10% of the Massachusetts industry. However, if we use number of employees, my sample represents even more than 10% of the population because the sample includes the largest firms in the state. Other descriptive information about the age and size of firms in the sample is presented in tables 2.4 and 2.5.

My main objective in these case studies was to understand the characteristics of production jobs in biotech firms and how they vary with stage of development and market segment. However, assessing production is difficult because only a few Massachusetts companies are manufacturing for commercial sale at present. Most are manufacturing for clinical research and expect to manufacture for commercial sale once their products are

[4] I borrow this term from Blakely & Nishikawa (1990, p.8), who define DBFs as "entrepreneurial ventures started specifically to commercialize innovations in biotechnology." The first DBF was Cetus, which was founded in California in 1971. DBFs are distinguished from pharmaceutical or chemical companies, which generally are older and do not exclusively use modern biotechnology in their production processes.

approved for sale. My sample includes a couple of firms which are manufacturing for commercial sale, or are fully equipped to begin commercial manufacturing pending product approval. Other firms in the sample are manufacturing products for purposes of clinical trials, which comes before commercial manufacturing.

Generally, I interviewed the senior person in charge of personnel, i.e. Vice Presidents of Human Resources. In the case of several small firms, I was also able to interview the Chief Executive Officer. I also interviewed other people as well, including industry consultants, scientists, education and training people, biotech plant managers. These people helped give a fuller perspective of the employment issues in biotech production. Twenty-four interviews were conducted in person or by phone between February and April, 1991.

Secondary Sources

I found some useful information to help answer my questions in several surveys done on Massachusetts biotech companies within the last couple of years. While I could have elected to do my own survey, there were several reasons that prevented me. First, firms were already complaining about being over-surveyed. Second, surveys would only provide fairly narrow and mostly numerical answers. I wanted to understand the employment strategies firms were using, and the factors influencing their choices. Finally, because a survey would be resource and time consuming, I decided to use the existing surveys and then to supplement them with interviews with a small sample of firms.

Basic information on firms including founding date, products, firm size, occupational and educational structure of the workforce was available from directories and recent surveys. However, surveys could not tell me how growth of production jobs grew and how the skills changed, nor did they contain information about the gender and racial composition of a company workforce.

Besides local surveys, I used findings from a 1980 study on California biotech firms reported in a UCBerkeley working paper by Ann Markusen. As well, I cite one private industry survey (Ernst & Young), which is taken annually of the biotech industry in the US. Finally, I draw comparisons in most sections with other industries, such as drugs (SIC 283),

which includes biotech therapeutical firms (SIC 2836) and biotech diagnostics (SIC 2835). I also make comparisons with computers and semiconductors (SIC 3571,-2,-5,-7, and 367). These sources are taken from the US Bureau of the Census and Massachusetts Department of Employment and Training.

Table 2.1
Biotechnology Products
on the US Market

Product	Treatment or Use (year first approved)
HUMAN HEALTHCARE	
Alpha interferon	hairy cell leukemia (1986), Kaposi's sarcoma (1988), non-A non-B hepatitis (1990)
Erythropoeitin	anaemia associated with kidney disease (1989)
Gamma interferon	chronic granulomatous disease (1990)
Human growth hormone	dwarfism (1996)
Insulin	diabetes (1982)
Tissue plasminogen activator	dissolve blood clots (1987)
Vaccines	hepatitis-B (1986)
Monoclonal antibodies (MAbs)	treat kidney transplant rejection (1986), purify blood clotting agents (1987)
DIAGNOSTIC TESTS (MABS and DNA probes)	diagnose pregnancy & fertility; bacterial and viral infections; genetic deseases DNA fingerprinting; forensic and paternity testing, etc.
AGRICULTURE	
Animals:	
Vaccines	colibacillosis or scours (1984), pseudorabies (1987)
Diagnostic tests	bacterial and viral infections, pregnancy, presence of antibiotic residues
Plants:	
Diagnostic tests	diagnose plant diseases (e.g. turfgrass fungi)
FOOD PROCESSING	
Diagnostic tests	diagnose food and feed contaminants (e.g. salmonella, aflatoxin, listeria)
Chymosin or renin	enzyme used in cheesemaking (1990)
OTHER	
Transgenic mice	cancer research
Luciferase TM	detection agent used in food and medical diagnostic tests

Source: U.S. Industrial Outlook, U.S. Dept of Commerce, 1990.

Table 2.2

STRATEGIC GOALS OF US BIOTECH
by Company Size

Company Size (percent of companies)	----- Strategy ----- 1	2	3	4	5
Small 1-50	66%	41%	59%	51%	38%
Mid-size 51-135	65%	63%	31%	35%	29%
Large 136-299	40%	68%	16%	16%	80%
Top Tier 300 + emp	44%	78%	13%	0%	90%
All Companies	61%	51%	46%	40%	31%

Source: Ernst & Young, Biotech 91: A Changing Environment

Notes: Strategy 1: Develop products that corporate alliance partners will market
Strategy 2: Become fully integrated company
Strategy 3: Establish enough value to attract an acquisition
Strategy 4: Establish enough value for an initial public offering (IPO)
Strategy 5: Develop core technology for licensing

Table 2.3

MASSACHUSETTS BIOTECH SAMPLE
By Market Segment

(11 Companies - 1991)

Product Sector	Thesis % of sample	MBC Survey [5] % of sample	E&Y Survey [6] % of sample
Therapeutic	64%	41%	35%
Diagnostic	18%	39%	28%
Agriculture	18%	8%	8%
Suppliers	--	12%	29%
Total	100%	100%	100%

[5]. "An Assessment of the Massachusetts Biotechnology Industry", by Peter Feimstein Inc., October, 1990.

[6]. "Biotech 91: A Changing Environment," by Steven Burrill & Kenneth Lee, Jr. for Ernst & Young, 1990.

Table 2.4

MASSACHUSETTS BIOTECH SAMPLE
By Date of Founding

(11 Companies - 1991)

No. of Firms Total = 11	Before 1980	1980 1985	After 1986
Firms	9.1%	54.5%	36.4%

Source: Case Studies (1991)

Table 2.5

MASSACHUSETTS BIOTECH SAMPLE
By Size of Company

(11 Companies - 1991)

No. of Firms Total = 11	Small 1-50	Mid-Size 51-135	Larger 136-199	Top Tier 300+
Firms	18.2%	27.3%	18.2%	36.4%

Source: Case Studies (1991)

Chapter 3

Job Creation

INTRODUCTION

Recent estimates of biotech employment and future growth in Massachusetts threw cold water on expectations raised by the outgoing Dukakis administration that biotech would save the state's faltering economy and put people back to work. While biotech will produce needed jobs during hard economic times, it will not match the employment levels of computer and semiconductor industries.

This chapter explores the job creation process in biotech production, where most low- and semi-skilled jobs are created. Recent surveys provide current and future estimates of production jobs, but they do not explain how jobs are generated at different stages of product development. The major findings in this chapter are that:

1) Biotech production does not employ large numbers of people.

2) Production occurs in three distinct phases -- research & development, clinical trials, and commercial manufacturing. It takes place at the lab bench during R&D. Then during clinical trials, it typically moves into a separate space, or pilot plant, within the same facility. Finally, commercial manufacturing often requires a separate facility.

3) The number of production jobs increases between R&D and clinical trials, and skill levels begin to drop. The average pilot plant employs slightly more than 40 people, 2/3 of whom have at least a bachelor's degree.

4) For a given product, the number of production workers required for commercial manufacturing is not necessarily higher than for manufacturing in the pilot plant (depending on automation and potency of product). However, the majority of jobs in commercial manufacturing do not require 4 years of college. The average commercial plant employs 53 persons, almost 60% of whom have less than a bachelor's degree.

5) Some firms may pursue strategies that do not lead to growth in production employment

6) Production is already beginning to leave the state, and many firms will be making critical location decisions in the next 18 months.

Chapter 3 is organized in several sections, beginning with an overview of biotech employment in the US and in Massachusetts. Next, the focus is given to production employment. National and state data on production jobs is reviewed next, and that is followed by an analysis of the job generation process at the plant level for both therapeutic and diagnostic products. The fourth section explores several limitations on employment growth, including firm strategies and location decisions. Issues of skill requirements, access to jobs by women and minorities, and job quality are considered in later chapters.

Does Biotech Create Lots of Jobs?

Counting jobs in the biotechnology industry is difficult. First of all, biotechnology is a process used in many industries: primarily pharmaceutical, chemical, food and agriculture. Second, there are companies which were founded with the sole purpose of exploiting biotechnology processes (referred to in this study as dedicated biotechnology firms, or DBFs), while other companies may use biotechnology processes for some, but not all of their products. Finally, there are companies which make equipment used in the biotechnology industry.

The decision about which companies to include in estimating total jobs, and whether to count all employees or just those who are engaged in biotech processes, leads to different estimates of employment. For example, there are two annual estimates of biotech employment at the national level (see tables 3.1 and 3.2). The Bureau of the Census estimates that in 1990 there were 28,700 employees in diagnostic (SIC 2835) and non-diagnostic, or therapeutic (SIC 2836) sectors. Ernst & Young, a private consulting firm serving the biotech industry, estimated that there were nearly 50,000 employees in biotech in 1990. The truth depends on the biotech definition used, and on the availability and believability of data for the categories included.

Based on the government's 1990 estimate, biotech in the US is very small -- it represents only 16%, by employment, of the entire drug industry -- and even smaller compared to computers and semiconductors, which employed almost 28 times as many people

in 1990. However, since 1988, computers and semiconductors have shown job losses, whereas biotech (and most of drugs) added jobs. Computers and semiconductors are mature industries, while biotech is in its infancy.

Official government estimates of employment in biotech in Massachusetts are not available, but several surveys have attempted the task. The local estimates range (see table 3.3) from 13,600 to 17,585. Regardless of the estimate used, biotech represented less than half of one percent of total employment in Massachusetts in 1990 (see table 3.4), and approximately 6.4% of all high tech employment. High tech employed 212,200 people in 1990, which was down from 238,600 in 1988 (see table 3.5). Job losses in high tech between 1988-90 were twice the estimated number of total employees in biotech as of 1990. Even if the most optimistic projections for growth of Massachusetts biotech are correct and employment reaches 80,000 (see table 3.3) by the turn of the century, biotech will employ barely half of what high tech employed during the 1980s.[1] Biotech employers are the first people to agree with this assessment:

> *[Biotech] is not going to be the kind of industry, from a production staffing point of view, that will be equivalent to the DECs and Wangs of this world. It isn't a labor intensive kind of thing. A lot of it is automated. You're harvesting your product from processes that don't require an assembly line type of an approach.*

JOBS IN BIOTECH PRODUCTION?

Estimates of the number of biotech production jobs in the US in 1990 were 14,300, exactly half of all biotech jobs (see table 3.6). In Massachusetts, Feinstein estimated that 3,264

---

[1] Indirect employment from biotech companies in Massachusetts may be significant someday. However, it does not appear to be a major economic phenomenon at present. Among the three largest biotech firms in the study (and in the state), none had a major product licensed for sale in the US, so sales to local firms (forward linkages) are insignificant as of 1991. Firms were asked to estimate the percent of total annual purchases (supplies & services in dollars) derived from Massachusetts firms. Only one out of three firms could provide a rough estimate, which was more than 35% of annual purchases. Aside from capital equipment, the largest annual purchases of supplies are typically for scientific and production equipment and chemicals. All three firms said they buy from the same 3 major suppliers: VWR Scientific, Fisher Scientific, and Baxter Scientific Equipment. None of these firms is located in Massachusetts, although they have distribution offices located here. Average employment at each Massachusetts distribution company is estimated to be about 30 employees.

of 13,600 of biotech jobs were in production, which represents one quarter of the biotech workforce. The proportion of production jobs to all jobs in the national estimate may be inflated due to including older companies which have larger production workforces, and are counted because some fraction of their business is biotech. Feinstein forecasts that production jobs in Massachusetts will increase 686% by the year 2000. This means that the number of production jobs might increase from 3,264 (24% of total biotech workforce) in 1990 to 25,655 (32%) jobs by 2000.

PRODUCTION OCCURS IN THREE STAGES

Production occurs in three distinct phases during the life cycle of a product. Between each phase, the number of the employees changes, with the largest increase typically occurring during scale-up, the period when the company goes from producing small to large quantities of a product. Not all products are alike, and so not all production processes are alike. There are significant differences between therapeutic and diagnostic products, that mostly have to do with regulatory controls and the complexity of the production process. Second, there can be variation among therapeutic products due, again, to regulatory controls, but also to product concentration and potency, and automation.

Each of these characteristics influences employment and will be discussed in this section, but first, we should briefly review the production process itself to provide background. In so doing, I will use the therapeutic market segment as the basis for the description, because it helps to clarify the different employment outcomes. However, later, in the section, an example of employment growth during the product development cycle of a diagnostic product will be given.

Like all drugs, biotech products are heavily regulated. These regulations demarcate the three phases in the production process. Before a vaccine or therapeutic treatment can be sold in the US, a company must demonstrate that it is safe and effective, and can be manufactured consistently. Before a drug can be tested in clinical trials, an Investigational Drug Application (IND) must be filed with the Food and Drug Administration (FDA). If tests show that the product is safe and effective, then a second permit, the Product License Application (PLA) is granted. In addition, the manufacturing process itself must be validated

to show that the product can be produced consistently and meet current good manufacturing practices (GMPs). After PLA and validation, then the product can be made and commercially marketed (see table 3.7).

1) RESEARCH & DEVELOPMENT: LABORATORY BENCH

The first stage occurs during R & D when small quantities of product are needed for laboratory investigations. Quantities, in the range of 1 - 50 litres, can be produced at the same lab bench where R&D occurs. This phase may last up to a year or more for a therapeutic.

There are usually fewer production steps in R & D than later stages, since the end result is not a finished product. Steps include: i) cell culture and fermentation, where desired cells, or cell parts (e.g. proteins), are grown, ii) primary recovery, where the product is captured, and iii) purification of product into bulk form. Production is usually carried out by several scientists and engineers, with assistance of one or two non-degreed people, who wash glassware, care for laboratory animals, and/or prepare solutions. Total staffing is probably not more than 5 persons.

2) CLINICAL TRIALS: THE PILOT PLANT

The second stage occurs after an IND permit is granted, and can take up to several years. At this time, larger quantities of product (50 - 100 litres, depending on the potency) are needed to supply clinical trials. Production may expand to several benches within the lab, or move into a separate pilot plant, usually in the same building. Pilot plants are not large. Generally, they range in size from 5,000 to 20,000 square feet.

Process steps begin to increase in the pilot plant, adding to those mentioned above a iv) formulation step, where the bulk product is stabilized for delivery into the blood stream, v) a filling step, where the product is put into one of several forms (e.g. capsules, vials, freeze dried, etc), and vi) a packaging step, where product is boxed, labelled, and shelved. The production process in the pilot plant is still undergoing development and change. It is not yet routine.

At this time, a plant manager is hired, along with several supervisors, as many as 10 process operators, a quality control (QC) specialist, one or two filling technicians, a couple of utility specialists who maintain boilers and other equipment, and one to two people to handle packaging and shipping, if required. Total staffing might reach as much as 50 people, most of whom will be degreed. Based on a local sample, the average workforce in the pilot plant is estimated at 41 employees, two-thirds of whom are degreed (see table 3.7). Because economies of scale have not been fully achieved, pilot plants are often more labor intensive than commercial facilities.

3) MANUFACTURING: THE COMMERCIAL PLANT

When a PLA permit is received, production goes through scale-up, during which time the biological, chemical, and engineering issues associated with increasing production by factors of 10X, 100X, or even 1000X, are worked out. This increase from the pilot scale is usually not linear, however, and presents serious technical challenges. Typically, a separate and dedicated commercial facility is established in the range of 50,000 to 200,000 square feet.

While fermentation volume may reach as high as 100,000 litres, scale-up does not mean that the number of employees increases in proportion to the product. The same person who operated a fermenter with a 10 litre capacity, can be trained to operate a fermenter with a 10,000 litre capacity. Process steps do not change appreciably, but are made routine and followed religiously to avoid the risk of losing federal license to manufacture.

After the commercial facility is created, the pilot facility is likely to be assigned to a new product for process development. Some employees from the pilot facility may move to the commercial facility, but most of the staff for the commercial facility will be new hires. Additional utility technicians, process operators, and packaging and distribution people will be added. Total employment may increase beyond the pilot plant. Or it may actually decrease due to economies of scale and automation. Based on estimates from several firms, the average employment in commercial plants would be 53 persons (see table 3.8).

Other variables affecting growth

There are a number of variables which affect employment in the biotech plant. Broadly, these variables fall into two categories: those over which companies do not have much control, and those over which they do exercise control. In the first grouping are those qualities inherent in the product (concentration and purity) and regulatory requirements. The second grouping includes things like automation, company goals, and strategies.

Product Concentration & Differences

The biotechnology revolution enabled certain products to be produced in much greater quantity, concentration, and purity than were possible before using traditional processes. In this respect, the technology is labor saving. If a product is very potent to begin with, then fewer employees are needed to grow adequate amounts of it. A highly concentrated product may actually require fewer employees when it is manufactured in a commercial facility than in the pilot plant. In other words, if 1,000 effective doses can be obtained from 1 litre of material, versus 10 doses, then scale-up allows fewer employees to produce large quantities of product.

Some products are more labor intensive than others, because they require extra processing steps or because of special regulations pertain to their manufacturing. Some products are simply difficult to make because they require extra steps to process and purify. Occasionally, chemical modifications must be made. All of these additional steps require extra hands, and so increase the number of employees who will be hired.

Other products require extra processing steps because of regulations. This is the case with biopharmaceuticals, which are injected into the bloodstream. The FDA requires additional steps and precautions to ensure purity and consistency. As a result, more inspectors must be hired, as well as quality control and quality assurance personnel. By contrast, manufacturing antibiotics is simpler because they are not as regulated (see table 3.9). One plant manager estimated that biopharmaceuticals employ 1/3 to 1/2 more workers than antibiotics.

Regulations matter in diagnostic products too. Those used outside the body (in vitro) are not as strictly regulated as those used inside the body (in vivo). The other difference between diagnostic and therapeutic products is that diagnostics tend to have more pieces to package. Therefore, diagnostic products often hire more people for packaging, distribution, and warehousing. The addition of employees for a diagnostic product are shown in the typical Table 3.10. Most of the 11 people added in the commercial phase are assemblers.

Automation

The incentives to automate biotech production include reducing the labor bill, and improving consistency and accuracy of data collection used to show compliance with federal regulations. Everyone interviewed said that automation is widely practiced, and likely to increase in the future. One employer explained the incentives and limitations of automating production for her company as follows:

> *The number of people you decide to hire in production and how much you streamline depends on how much you automate. The issue we have with automation in diagnostics is that you have a short product life cycle, which discourages automation. Having said that, I would say that our products are fairly automated... We have chosen to automate first those processes that are the most labor intensive that we saw ourselves continuing for several years... [But] in real small lots you still fill by hand.*

Company Strategies & Alliances

A common goal of the biotech firms, who started 10 years ago, was to become an integrated company, including manufacturing, marketing, and sales infrastructures. However, the Ernst & Young survey reveals that company strategies are more diverse today. Not all companies do plan to become fully integrated. Instead, some firms say their goal is to license technology. One CEO referred to these companies as 'research boutiques.' They engage exclusively in research, and ignore manufacturing altogether. As a result, they do not plan, nor show much employment growth. Some companies even claim their goal is to *'establish enough value to attract acquisition'* (Ernst & Young, 1990, p.26 -- see table 3.11).

One of the most common strategies used by biotech firms is the strategic alliance. Alliances are struck for purposes of research, production, marketing, and/or sales. US biotech companies say they engage in three strategic alliances on average (Ernst & Young, 1990, p.39). Most alliances are formed in order to take advantage of the partner's marketing capability, but 17% of the companies use alliances for manufacturing (see table 3.12). Production employment in Massachusetts is hindered when a firm chooses to license its technology to a firm outside the state, who manufactures that product in its own facilities. Currently, most of the products developed by Massachusetts biotech firms are being manufactured outside the state by large pharmaceutical and chemical companies.[2]

Licensing may decline in the future if companies develop internal production and marketing capabilities of their own. However, if the strategy becomes a permanent fixture (as warned by Blakely and Nishikawa, 1990), then we are likely to see production growth in Massachusetts inhibited to a degree. One experienced CEO, observed that his company's use of alliances is changing.

> *Four or five years ago, 90 percent of what we were working on in the research pipeline had already been licensed. Today, that's flipped. We own worldwide rights to 90 percent of our R&D today. We'll do more licensing, we'll do more deals, but they will be more strategically than economically driven.* James Vincent, CEO, Biogen, (Ernst & Young, 1990, p.103).

In reflecting on what he would do differently today, another CEO from Massachusetts, said,

> *I would have insisted on complete manufacturing rights on all licensing deals, and have moved faster to retain clinical development control.* Gabe Schmergel, CEO, Genetics Institute, (Ernst & Young, 1990, p.103).

LOCATION

Alliances are not the only strategy currently limiting employment growth in biotech production in Massachusetts. Some firms are choosing to establish manufacturing facilities outside the state. There are also signs that firms will do their manufacturing off shore. Three

[2] Information obtained from company annual reports.

of the eleven firms participating in this study have manufacturing facilities, or warehouses in other states, and three have manufacturing facilities overseas (see table 3.13).

Despite the beginnings of decentralization, most biotech firms are still concentrated in the Cambridge area, because they want to remain close to the universities where many of their founders teach, and where they can tap scientific advances as soon as they happen.

> *We are and will always be a science driven company. Not quite half of the founders of this company are still with Harvard and MIT. Having the ability to access the scientific innovations that are going on in the academic research laboratories is important to us.*

But Cambridge may not be ideal for manufacturing, because land is scarce and expensive. Companies also mention their concern about the regulatory environment.

> *Cambridge is a very constraining environment. Are we going to have an environment that is conducive to setting up a production facility, or are we going to have environmental issues that would be too overwhelming to allow us to stay here, versus going to Rhode Island, New Hampshire, Puerto Rico, or Ireland. Our preference would be closer proximity than to have to get on an airplane to go see the production facility.*

Cambridge is not the only hot spot in Massachusetts. Worcester, which boasts several universities and a teaching hospital for medicine, is home to half a dozen biotech companies. Town leaders have put together a set of regulations that companies find attractive. With help from the state, Worcester created a science park for biotech companies. Recently, BASF, one of the world's largest corporations chose Worcester to establish their newly created bioscience laboratory. Local BASF officials speak with enthusiasm about Worcester.

> *Worcester had the infrastructure that no one else had. It had the Biotech park all set up to lure biotech companies. They had the legislation in place. Worcester city fathers and business people were ready for biotech -- encouraging, and wooing biotech. It was ready made for us. We didn't have to wait for regulations and laws concerning biotech research. It was all there, and they wanted it. The Worcester community is extremely supportive.*

While Massachusetts still retains its appeal as a hotbed for science, firms are looking outside the state as they mature, plan production facilities, and plan strategies for entering

world markets. They do not have to wait to learn what other states and countries have to offer. Every person interviewed for this study mentioned that they were regularly contacted, and occasionally offered tempting deals, by more aggressive governments.

There are tradeoffs to keeping operations in the same vicinity. One executive expressed the view that commercial production facilities should be far enough away from R&D to prevent the R&D from influencing production.

> *Once you're up doing commercial manufacturing, you want to be sure you're not doing research. A lot of people argue the opposite. They say they like to have their manufacturing close to their R&D so it will be easier to put in different new technologies and techniques. I think that's dangerous, because when you're doing manufacturing on a commercial scale, you want to make sure you do it the same way, every day, all the time. So you don't want to have the research, innovative influence on that. You want to do that in a pilot scale to get everything worked out, because going in to change your process and getting the FDA to accept it is not trivial.*

By no means is this philosophy true for every company. One of the state's largest therapeutic producers has kept all of its facilities in Cambridge. A production manager there said he would not want a dedicated commercial facility to be more than one hour away from the R&D operations, because of the need for frequent visits. However, two production managers from other therapeutic companies were not adamant about keeping facilities in the same state.

Because the regulatory requirements for diagnostics are less severe, these companies seem more content with present facilities. Both diagnostic firms in the sample have all of their operations contained within one building. A CEO from one of these firms offered a rule of thumb about expansion and relocation for a diagnostic company:

> *For a diagnostics business up to $50 million in sales, I'd just as soon have it all under one roof. I think that there are significant benefits.... I mean these aren't anvils we're making, so you just can't ship a blueprint up to Ottumwa and have them read the blueprint and go make the anvils. These are very delicate biological systems, and they're changing all the time... and from time to time they don't work... So to be able to have the development scientist and the production scientists sit down and do problem solving together without having to charter airplanes -- I think -- is a distinct benefit. Beyond that, you might have administration and distribution under one roof in Massachusetts, and take both production and development and put them in Bellbrook,*

Ohio or somewhere. But I think I'd keep those two (production and development) together, and this is based on my experience at [another diagnostic firm], where one of my predecessors decided to split up R&D and production and it was disastrous. It almost spelled the end...

Agriculture may be different from therapeutics and diagnostics. While most of the agricultural biotech firms in Massachusetts are still in R&D, Biotechnica International, the state's largest player in agricultural biotechnology, recently decided to relocate to the midwest. The only agricultural company in this study said, unequivocally, that when the company reaches commercial production for their agriculture product,

... we would not do manufacturing in Massachusetts. One of the issues is raw material. The material we use is a corn gluten protein, so we want to be close to where they mill the corn...

Europe and Puerto Rico are likely to be winners of biotech production facilities in the future. One CEO explained the reason his company opened shop in Europe:

If you are to succeed, you must access that marketplace. To do so, a company must have a manufacturing presence in Europe. It's much easier to get products into the international markets if they're made locally there. US made products take much longer.

Puerto Rico is equally attractive to companies because of tax advantages and a large pharmaceutical infrastructure on the island. More than 85 pharmaceutical companies have operations in Puerto Rico, manufacturing about half of all pharmaceutical products sold in the US.[3] In the Boston Herald story, one company executive said that:

We would jump to Puerto Rico in a New York second if Massachusetts does not provide us with some sort of incentives, because Puerto Rico does.

[3] Puerto Rican Economic Development Administration, cited in Boston Herald, 4.23.91. p.28.

CONCLUSIONS

The major implications of this chapter's findings are:

1) The absolute numbers of production jobs created by biotech in Massachusetts are quite small. Even the most optimistic forecasts, if they come true, project that biotech will employ less than half of what computers and semiconductors employed in the state during the 1980s.

2) Biotech production creates more jobs than R&D, and it mostly creates jobs for low- and semi-skill labor. Therefore, if the state is going to target this industry, it must develop effective strategies for supporting biotech manufacturing.

3) The critical growth in production for non-degreed labor comes as clinical trials end, and scale-up to commercial production begins.

4) Employment volume varies with product, market segment, and firm strategy. Some companies are more likely to generate jobs than others.

5) Scale up is also the time when companies consider establishing production facilities. And there is a good likelihood that companies will set up production outside the state. However, some companies realize there are incentives to keep facilities in state.

Table 3.1
Total Employment in U.S. Biotechnology &
Other High Tech Industries
Actual and Estimated, 1987-1991

Employment	1987	1988	1989	1990	1991	----Percent Change----- 1987-1988	1988-1989	1989-1990	1990-1991
Total employment (000)	172	174	176	178	181	1.2%	1.1%	1.1%	1.7%
2833 Medicinals & botanicals	11.6	11.4	11.7	11.6	11.8	-1.7%	2.6%	-0.9%	1.7%
2834 Pharmaceutical preps	132	135	136	138	140	2.3%	0.7%	1.5%	1.4%
2835 Diagnostic substances	15.4	14.5	14.8	15	15.1	-5.8%	2.1%	1.4%	0.7%
2836 Bio prod ex diagnostic	13.3	13.2	13.4	13.7	13.7	-0.8%	1.5%	2.2%	0.0%
3571, -2, -5, -7 Computers & Peripherals	286	289	289	277	270	1.0%	0.0%	-4.2%	-2.5%
367 Electronic Components (Including Semiconducters)	547	561	533	520	506	2.6%	-5.0%	-2.4%	-2.7%

Source: U.S. Department of Commerce: Bureau of the Census; International Trade Administration (ITA). Estimates and Forecasts by ITA
1988 Advance data from the 1988 Annual Survey of Manufactures.
1989 Estimate
1990 Estimate
1991 Forecast

Table 3.2

Regional Distribution of Biotech Employees
(1990)

Region	Number of Employees	Employment in percent
San Francisco Bay Area	12,456	25.0%
New York Tri-State ARea	7,043	14.1%
BOSTON AREA	5,492	11.0%
Washington D.C. Area	4,343	8.7%
San Diego Area	3,329	6.7%
Seattle Area	2,183	4.4%
Los Angelos/Orange County	2,102	4.2%
Iowa	1,440	2.9%
Philadelphia Area	1,041	2.1%
Ohio	1,005	2.0%
Minnesota	998	2.0%
St.Louis Area	987	2.0%
Texas	885	1.8%
Utah	736	1.5%
Geogia	714	1.4%
Indiana	710	1.4%
Colorado	621	1.2%
Illinois	513	1.0%
Other	3,227	6.5%
Total	49,825	100%

Source: "Biotech 91: A Changing Environment" by Steven Burrill & Kenneth Lee, Jr. of Ernst & Young, 1990.

Table 3.3

GROWTH ESTIMATES FOR MASSACHSUETTS BIOTECH FIRMS
Total Employment, Production Employment and
Percentage Growth 1990-2000

	1990	1993	1995	2000
Total Employment				
Feinstein	13,600	21,352	-	79,968
EDIC	17,585	-	30,422	-
Production Employment				
Feinstein	3,264	6,300	-	25,655
EDIC	-	-	-	-

Percent Increase From 1990

	1993	1995	2000
Total Employment			
Feinstein	57.0%	-	488.0%
EDIC	-	73.0%	-
Production Employment			
Feinstein	93.0%	-	686.0%
EDIC	-	-	-

Source: Peter Feinstein, Inc., 1990, (N = 66, all are members of the Mass Biotech Council)

Economic Industrial Development Corporation, "Growth in the Ninties: Prospects for Strategic Economic Development in Boston", January, 1991.

Table 3.4

Massachusetts Employment Levels
All Industries, Biotechnology, & High Tech

Industry	Employment	Percent
TOTAL EMPLOYMENT (all industries)	3,014,700	100.0%
BIOTECHNOLOGY		
Ernst & Young	8,000	0.3%
Feinstein	13,600	0.5%
ALL HIGH TECH * (includes: 36, 38, 376, 379, 357, 348, 283)	212,200	7.0%
Biotech as % of High Tech		
Ernst & Young		3.8%
Feinstein		6.4%

Source: Total Employment (Bureau of Labor Statistics), includes all employed people in 1st quarter of 1990.
Ernst & Young, 1990, and Peter Feinstein, Inc., 1990, both estimates based on industry surveys.
Massachusetts Dept. of Employment & Training, 1991.
'HIGH TECH' defined by MASS DET, includes some non-high tech.

Table 3.5

Massachusetts High Tech Job Levels
& Job Losses

Employment	1989	1990	89-90
HIGH TECH (includes 36, 38, 376, 379, 357, 348, 283)	238,600	212,200	
JOB LOSSES IN HIGH TECH			(26,400)

Source: Massachusetts Dept. of Employment & Training, 1991.
'HIGH TECH' defined by MASS DET, includes some non-high tech.

Table 3.6

US Trends and Forecasts in Biotech & Other High Tech Industries
TOTAL PRODUCTION EMPLOYMENT

EMPLOYMENT	1987	1988	1989	1990	1991	Percent Change 1987-88	1988-89	1989-90	1990-91
Production workers (000)	79.6	81.4	82.3	83.4	83.7	2.3%	1.1%	1.3%	0.4%
2833 Medicinals & botanicals	6.1	6.2	6.2	6.4	6.3	1.6%	0.0%	3.2%	-1.6%
2834 Pharmaceutical preps	59.9	61.6	62.2	62.7	62.9	2.8%	1.0%	0.8%	0.3%
2835 Diagnostic substances	6.8	7.3	7.6	8	8.1	7.4%	4.1%	5.3%	1.2%
2836 Bio prod ex diagnostic	6.8	6.3	6.3	6.3	6.4	0.0%	0.0%	1.6%	1.6%
3571, -2, -5, -7 Computers & Peripherals	101	105	105	103	101	4.0%	0.0%	-1.9%	-1.9%
367 Electronic Components (including Semiconducters)	330	343	333	327	320	3.9%	-2.9%	-1.8%	-2.1%

SOURCE: U.S. Department of Commerce: Bureau of the Census; International Trade Administration (ITA). Estimates and Forecasts by ITA
1988 Advance data from the 1988 Annual Survey of Manufactures.
1989 Estimate
1990 Estimate
1991 Forecast

TABLE 3.7

Biotechnology Industry
Approval Cycle for a Medical Therapeutic Product

PHASE	GENERAL ACTIVITY	TIME SPAN
Preclinical)	Research and testing on animals for efficacy & toxicity as well as replicating production.	1 - 2 yrs
IND	Filing of "Investigative New Drug" application. New data requests could require 6-12 months of additional testing.	1 - 2 mths
(Clinical Trials)		
Phase I	Tests on healthy humans at multiple centers to determine product safety.	1 - 2 yrs
Phase II	Tests on limited group with the medical problem to determine product safety.	1 year
Phase III	Test of large numbers of patients to determine product efficacy.	2 - 3 yrs
Final FDA Approval (NDA)	Collection, correlation, preparation & submission of test data and product review.	1 - 2 yrs
	TOTAL	6 - 10 yrs

Source: "Biotechnology Industry Analysis," S. Brainard, M. Podsedly, & L. Sutlif. Boston College Graduate School of Management. Chestnut Hill, MA. 1989.

Table 3.8

BIOTECH EMPLOYMENT GROWTH

Pilot & Commercial Plants
Therapeutic Firms

	Company 1	Company 2	Company 3	Average All Firms	Percent %
AVERAGE PILOT PLANT					
Total employees	40	33	50	41	100.0%
Degreed	28	29	25	27	65.9%
Non-degreed	12	4	25	14	34.1%
AVERAGE COMMERCIAL PLANT					
Total employees	40	70	50	53	100.0%
Degreed	12	53	5	23	43.4%
Non-degreed	28	17	45	30	56.6%

Source: Case Studies of 3 Mass biotech firms, 1991.
Data are based on estimates.

Table 3.9

EMPLOYMENT GROWTH BY PRODUCT TYPE IN THERAPEUTICS
during scale-up

Type of Plant & Product	Total Employment low	high	AVG.
PILOT			
Pharmaceutical	15	50	33
Antibiotic	10	33	22
COMMERCIAL			
Pharmaceutical (if pilot = 50)	25	30	28
Antibiotic (if pilot = 33)	17	20	18

SOURCE: Case study of Mass. biotech manufacturing, 1991.
NOTE: Commercial employees represent additions to employees of pilot facility.

Differences between Biopharm & Antibiotic
Therapeutic Products

Biopharmaceuticals	Antibiotics
injectable into bloodstream	not necessarily injectable
more heavily regulated	less regulated than biopharm
more processing steps	fewer processing steps
must remove DNA and any virus in product	purification is simpler
	employs 1/2 - 2/3 number of employees as biopharm

Table 3.10

EMPLOYMENT GROWTH FOR DIAGNOSTIC PRODUCT
by Each Production Stage
by workforce degree

	R&D	Clinical	Commercial	TOTAL
Total employees	3	2	11	16
Degreed	3	2	0	5
Non-degreed	0	0	11	11

SOURCE: Based on case product for MA diagnostic firm, 1991.
Data are based on estimates.
Note: Degreed = bachelor's plus
Non-degreed = less than bachelor's

Table 3.11

Biotech Firms & Plans for Consolidation
within the next 5 years
by company size

	To Acquire a Smaller Firm	To Be Acquired By a Larger Firm	To Merge With an Equal-Size Firm
Small 1-50 emp.	37.0%	48.0%	39.0%
Mid-Size 51-135 emp.	54.0%	21.0%	17.0%
Large 136-299 emp.	76.0%	30.0%	25.0%
Top Tier 300 + emp.	74.0%	22.0%	22.0%
All Companies	47.0%	39.0%	32.0%

SOURCE: Ernst & Young, "Biotech 91: A Changing Environment"

Table 3.12

REASONS FOR PARTNERING
Biotech Companies with Alliance in the U.S.

	Mktg. Ability	Capital Needs	New Products	Mfg. Ability	Science/ Techn'g
Diagnostic	83.0%	29.0%	19.0%	27.0%	10.0%
Therapeutic	59.0%	55.0%	10.0%	14.0%	17.0%
Ag-bio	46.0%	54.0%	17.0%	17.0%	80.0%
Supplier	71.0%	31.0%	38.0%	13.0%	80.0%
All Companies	64.0%	45.0%	20.0%	17.0%	15.0%

SOURCE: Ernst & Young: "Biotech 91: A Changing Environment"

Table 3.13

Location of Biotech Facilities
of 11 firms in Massachusetts
Case Study - 1991

MASSACHUSETTS		
	Same Bldg.	36.4%
	Separate Bldg Same City	18.2%
	Separate MA. Cities	27.3%
NON-MASSACHUSETTS		
	Separate State	27.3%
	Off Shore	27.3%

SOURCE: Case Studies (1991)
Note: #4 & 5 are not mutually exclusive

Chapter 4
Skill Requirements

INTRODUCTION

In chapter three, I presented my findings on job growth in dedicated biotechnology firms (DBFs) and important location trends likely to influence job growth. While policy-makers are anxious to promote job growth, I have argued that equal attention must be paid to enhancing opportunities for underserved populations and promoting good jobs. The next three chapters present the results and analysis of biotech production jobs from the standpoints of access and quality. Job access is considered in two parts: first in terms of skill requirements (chapter 4), second in terms of gender and race/ethnicity (chapter 5). Job quality is analyzed in chapter 6.

In this chapter, the major findings about skills are:

1) Biotech employers are currently hiring nearly twice the proportion of degreed workers than are represented in the Massachusetts workforce.

2) Despite popular stereotypes, semi- and low-skill jobs do exist in biotechnology firms, and will increase in the future.

3) Low- and semi-skill jobs are more commonly found in mature firms than R&D firms, and in diagnostic firms than in therapeutic companies.

4) In addition to education and experience, some entry level jobs require spoken & written fluency in English, which will prevent some immigrants from accessing these jobs.

5) Sterile manufacturing techniques and familiarity with Good Manufacturing Practices (GMP) are transferable production skills to biotech. Some Massachusetts companies are hiring production workers with these skills from high tech and food processing industries.

Each of these findings is taken up below in a separate section. In the following discussion, *low-skill* means that a high school degree is required, but generally no additional experience. *Semi-skill* means that special training and/or an associate's degree is required. *High-skill* means bachelors degree or higher.[1] For ease of presentation, *non-degreed* is used from time to time to combine low- and semi-skill. *Degreed* means education including and beyond the bachelor's level.

ARE THERE JOBS FOR NON-DEGREED WORKERS?

People often mistakenly assume that all jobs in biotechnology companies require an advanced degree in the life sciences. While it is true that the industry is very much on the cutting edge of recent advances in micro-biology, commercial biotech firms must still employ people to manufacture their products in jobs that do not require 4 years of college.

Table 4.1 presents the research results on education requirements of biotech firms in my sample compared with the educational attainment levels of the entire Massachusetts labor force. Because my sample is based on case studies, we cannot generalize about all firms in Massachusetts, nor about other states. It is likely to err on the side of counting more non-degreed workers, because older firms (founded before 1982) were deliberately oversampled. Their workforce is likely to be more diverse in terms of skill than younger firms, who we would expect to have a larger share of degreed workers.

In table 4.1, we see that the educational composition of the biotech workforce is very different than that of the entire Massachusetts workforce. While fewer than one-third of biotech workers are non-degreed based on this sample, almost two-thirds of the Massachusetts workforce is non-degreed. This difference suggests that a real skill mismatch exists between the industry and the state's workforce. Most biotech jobs will be inaccessible to most of the state's residents. However, at least one-third of all biotech jobs (and maybe more if requirements relax as the industry matures) are accessible to workers with less than a bachelor's degree.

[1] According to this definition, there are several levels of high skill within biotech. There are people with bachelors, masters, and PhDs. Although these educational differences are significant, they are not relevant to this study.

If we generalize based on the case studies, then nearly 30% of all jobs in current biotech firms do not require a bachelor's degree. If we apply this figure to the Feinstein estimates reported in chapter 3 (refer to table 3.3), then approximately 4,000 of 13,600 current jobs in biotech are accessible to non-degreed labor. Similarly, if growth projections for the year 2000 are accurate, then about 22,000 of the 75,000 + jobs will be accessible to non-degreed labor. However, education requirements are likely to change in favor of hiring more non-degreed labor, in which case the numbers of jobs mentioned above would be low end estimates.

Production jobs represent the largest share of all low- and semi-skill jobs found in firms (usually 60% in the case studies). R&D includes several positions for low-skill labor (e.g. glass washers) and semi-skill positions (e.g. lab assistants, media preparation technicians, and animal care personnel), and administration includes clerical support, which can be both low- and semi-skilled. Clearly, production is the most important area of biotech activity if we hope to see jobs created for non-degreed workers.

Table 4.2 illustrates the differences between diagnostic and therapeutic firms in terms of educational attainment levels of the firm's workforce. On average, 25.5% of the total workforce of the three therapeutic firms in the sample were non-degreed, whereas 42.6% of all workers in the diagnostic company were non-degreed. All firms in this comparison are roughly the same age. However, the diagnostic company has been manufacturing for commercial sale for several years, while the therapeutic companies are either licensing production of their approved products, or are awaiting product approval.

Job Requirements for Production Occupations

Biotech firms distinguish between low- and semi-skill workers. This distinction has been largely ignored in recent surveys of Massachusetts biotech companies. If surveys mention requirements for entry-level positions at all, they generally address semi-skill, to the exclusion of low-skill jobs. In order to plan to meet present and future labor needs of the biotech industry, as well as to enhance job access, it is important to understand that there are different skill needs, and that these needs change over time.

The rest of this chapter includes three sections. The first section describes the requirements for semi- and low-skill jobs. The second section describes how skill requirements change as firms mature. And the third section describes how hiring strategies have evolved over time, and how biotech firms have coped with skill shortages by hiring workers from other industries where workers have transferable skills.

SEMI-SKILL PRODUCTION JOBS

Skill requirements vary according to the area of production and the level of responsibility. While job positions and job titles vary from firm to firm, there is a basic set of job categories in biotech production, which are listed and grouped by skill level in table 4.3.

Semi-skill positions exist in the areas of 1) process development, 2) cell-culture or fermentation, 3) separation and purification, 4) aseptic fill, 5) quality control and assurance, and 6) facilities operation. The semi-skill job titles are typically called manufacturing technician, instrument technician, and quality control inspector. Employers typically look for three types of people to fill semi-skilled jobs:

A) Someone who has several years experience (but may not have an associates degree) in sterile manufacturing and with Good Manufacturing Practices (GMP). Sterile manufacturing is required by federal law for all human drugs to ensure safety and effectiveness. Workers must be familiar with the techniques and work environment.

B) Someone who has an Associates degree in biotechnology or related health field (but may not have previous work experience) where sterile manufacturing and laboratory techniques are taught.

C) Someone who has a special certificate or license, such as the American Laboratory Animal Technician's license (ALAS) for handling animals or fireman's license for boiler operation.

Besides familiarity with federal GMP standards, employers say they want to hire people who understand the basic equipment including fermenters, cell harvesters, and

centrifuges. To acquire this knowledge, says one employer, *"You don't need a four year degree person, but you want a skill level that's higher than just high school..."*

LOW-SKILL PRODUCTION JOBS

The areas of production that require less skill than those described above, are 1) facilities operation, 2) assembly, and 3) warehousing & distribution. Sometimes, there are low-skill, entry positions below the technician level in other process areas as well. These positions are usually called 'operator' or 'manufacturing assistant.'

Operators, and other entry-level positions, are involved in measurement and documentation, preparation and transference of solutions, and handling equipment and supplies. "[An] *operator is basically a no-skill job... It doesn't require a rocket scientist to do it, but it does require someone who is detail oriented, who can read numbers... can understand decimal points, and can weigh raw materials.*"

English

Being able to do basic math and follow instructions is not all that is required of entry-level jobs, say biotech personnel executives. English is also required. Employers say that because of federal regulations, their employees must be able to communicate and understand written and spoken directions. Safety considerations were also given as a reason for requiring English. Several firms said they have had problems in the past with employees whose weak English skills detracted from the company's operations.

> *We have a lot of foreign nationals in assembly who speak English, which is required for safety and instructions... because they have to understand Good Manufacturing Procedures. Every one of them has to understand that when you switch products, you literally have to clean up the whole area, get rid of everything on the old lots, and then check to make sure that when the new batches come in they have the right serial numbers and so forth.*

The language requirement was a consistent theme throughout the interviews regardless of whether companies were serving diagnostic or therapeutic markets. While language fluency

may not seem like an unreasonable requirement, it may exclude or limit immigrant workers, whose English skills may be weak, from gaining employment in certain skill areas in biotech.

Skills Change as Firms Mature

We saw in the previous chapter that production increases in proportion to R&D as firms mature. Likewise, the requirements for different skill levels also undergo changes as firms mature. It is important to recall the stages of product development to highlight the types of skills required at each stage. Opportunities for low- and semi-skill labor increase with each stage. Table 4.4 shows how the percentage of non-degreed production workers rises from R&D to clinical to commercial based on data taken from the case studies. The reader should note that company C in table 4.4 is not yet fully commercial, so we could expect even higher levels of low-skill labor than are seen at this point.

The skill changes are best described below by the employers themselves:

1) Research & Development - Laboratory Bench:

I consider my entry level here [in R&D] to have a bachelor's degree. It's a much more highly educated population. Anybody in the lab doing research has to have at least a bachelor's degree. There are a couple of people in the animal lab facility who have an associate's degree. Every single other person within that lab has to have a bachelor's now and will in the future.

2) Clinical Trials - The Pilot Plant:

For the pilot plant, that's different,... the entry level there needs to be at least an associate's. We could probably get away with a lower level when it gets to production.

I'd be surprised, if when people were hiring initially for clean room environments, that they would go to high school educated. The risk you run is that if you screw up in a regulatory kind of way, you can put yourself in a lot of trouble. I wouldn't be in favor of doing it. I would want to bring in someone who has at a minimum some lab experience and understands the environment.

3) Manufacturing - The Commercial Plants:

Once we get to the point where we'll need to have a fully developed production capability, we know we won't be staffing it with people with biology and

biochemistry degree holders. It's not driven by the fact that you need people with those skills. You'll have some of those, but not a predominant number of them.

Plant managers were even more clear about the changes in skill requirements with each production phase than were the human resource people. One plant manager said that 1/3 to 1/2 of the pilot plant workforce would be typically be non-degreed, while as much as 90% would be non-degreed ('or tradespeople') in the commercial plant. Another manager said that the proportions of degreed and non-degreed in the pilot plant would be 70/30, and then reverse in the commercial plant.

Before a product can be approved for sale, the production process and facility have to be licensed. Because of federal requirements for product safety and consistency, commercial production processes become highly standard and routine. Procedures cannot vary without risking losing federal licenses to manufacture and sell the product. As a result, skill levels are higher in the pilot plant where the process is evolving continually, and are lower in the commercial plant because production has become more routine and automated. The profile of commercial production also reflects more low skill because additional finishing steps are added including assembly and packaging, which require no more than a high school degree.

Hiring Strategies Have Evolved Over Time

While product life cycle may offer the greatest explanation of the change in skill demands from r&d to commercial production, it does not capture the learning process, which has occurred in older firms. Nor does it explain the variations in hiring strategies among firms at the similar stages of development. Previous surveys have missed the element of change occurring within the industry with respect to hiring practices. The biotech industry is relatively young, and employers learn as they experiment with ways to meet their employment needs.

In this section, I present some of the hiring lessons learned by the older generation of firms in my sample (those founded before 1982). These lessons are important for understanding the industry. Firms have coped with their employment needs in several ways:

- by hiring people from other states;
- by substituting workers with bachelor's degrees where there is a short supply of experienced, but nonetheless non-degreed, workers, and
- by re-training workers from other local industries where comparable skills exist.

But the main pattern is that firms eventually choose to substitute non-degreed labor for workers with bachelor's degrees.

Since the beginning of biotech, there has been an unusually close alliance between universities and biotech firms. Many biotech firms were started by university professors and located near universities. One scientist, who worked with several DBFs (dedicated biotech firms) during the last decade, said that during those early years, "*we were like universities.*" The industry-university ties may have influenced decisions about who to hire.

> Another employer, with many years experience in personnel, gave this description: *When we were very small, we thought that the person answering the phone should have a masters in science so that they could understand the questions being asked. It was that mentality!... If we have a choice between experience and education, we would probably take education.*

When it came time to staffing production areas, many firms went to New Jersey, and the midwest, to recruit experienced production workers, because there are a large number of pharmaceutical and chemical companies located there. But relocating people was costly, so firms decided that recruiting out-of-state was not an effective long run solution to labor needs. Their next strategy was to hire recent graduates from the universities.

There are several good reasons why firms hired bachelor's degree holders for production positions. Research scientists were used to working with undergraduate and graduate students. They wanted people who were familiar with the equipment and practiced good lab procedures. Furthermore, there has continued to be a large supply of people with BS degrees graduating from Boston area schools each year.

Second, there is no pharmaceutical industry in the state from which to hire workers trained in sterile manufacture. If firms were going to have to train workers, they were more confident of training bachelor's degree holders than non-degreed people.

> *The reason we've actually gone after bachelors degrees at these levels is because we haven't been able to find trained workers. So, we thought that if it was an option of relocating an hourly paid person, or having a bachelors-level person for a year or two [who would then move on], we're going to take the bachelors first.*

However, the problem firms experienced with hiring bachelor's degreed people was that they did not stay long. The jobs the graduates were doing were relatively monotonous and the opportunities for advancement limited. Firms reported that people were leaving after one year because they were getting discouraged. While this strategy might have worked in the short term, companies knew it would be too costly in the long run. Another problem with hiring recent college graduates is that while they may be familiar with laboratory equipment and procedure, they still need training with biotechnology equipment. One employer, in a diagnostic firm, said he preferred not to hire recent college graduates, because they required training that the company was not equipped to provide.

> *This isn't a very good place to train people... Previous academic experience is interesting, but it's not particularly valuable. We take graduates at the entry level only.*

The second strategy was to hire people with high school degrees with experience in industries where there was some skill compatibility. Employers have hired workers from industries where sterile manufacturing techniques and GMP practices were followed. Because of the lack of a developed pharmaceutical industry in the state, they hired operators from the food processing industry. However, one employer explained that they had problems with some of the food industry workers, because these workers were used to labor-management relations based on union contracts, which were unacceptable relations for this firm. The current hiring strategy among the largest firms is to hire a combination of people, including bachelor's degrees, associate's degrees in biotech or bio-medical studies, high school graduates

who have taken a laboratory course,[2] as well as workers from certain industries where skills may be transferable.

Skill Transferability from Other Industries

Employers are experimenting with hiring semi-skilled labor from other high-technology industries, such as electronics, pharmaceutical and diagnostic, and chemical, as well as non-high tech industries, such as food processing. This may be good news to workers who have lost jobs in the high tech industry (see table 3.5).

> *People can acquire that experience obviously in pharmaceuticals, but also in food industries, and we're hiring people out of high tech who have worked in microchip production...*

There seemed to be more interest among firms in trying to hire workers from electronics than real attempts to do so. At least one major employer thought it would be feasible for these kind of workers to make the transition.

> *We can get [production] people trained to operate in clean room environment in electronics, and transition them into skilled people who can work here. Having the background of a clean room environment is already an advantage for people who end up in production here... They ought to be available and trainable without it being a major issue.*

While the majority of the employers in this study expressed the view that skilled workers from electronics and food industries were suitable for re-training in biotech, some disagreed. One employer expressed doubts about whether former electronics workers would be good candidates for biotech jobs. He favored people from other agriculture, pharmaceutical, diagnostic, and food industries. Another employer even expressed the view that production operators from other pharmaceutical industries were not as ideal as might be expected. However, this view seemed to be in the minority.

> *In most cases they [production operators] haven't been in production facilities that equate to ours. They're making tablets. We're not necessarily making*

---

[2] According to the Boston School Department, there are 1,296 students enrolled in a college-bound, high school biology laboratory course during the 1990-91 school year. There are also 766 students enrolled in a non-college biology laboratory course. This group would be among the most likely candidates for entry-level, low-skill biotech jobs. (Figures are based on reporting by 12 out 16 schools).

tablets. We're making vials of product which are harvested from different type of processes. But they do have experience in drug manufacturing.

Training and Future Shortages

The availability of people with special training in biotech production is new as of this year. The Bay State Skills Corporation, together with biotech companies and several junior colleges, have designed, funded, and implemented several pilot training programs for biotech workers at three local junior colleges. The first batch of biotech certificates will be awarded in 1991. While some of these graduates may go to work in medical research institutions, it is expected that the majority will work in the private biotech industry.

The high school graduates do not have to have previous work experience, but employers prefer students who have taken a laboratory course or two. The largest companies say they have the capability to train workers for their present needs. But several companies expressed a concern that there could be a skills crunch in the near future as products in the regulatory pipeline gain federal approval. Once this happens, employers say they will need to hire more production workers. If several companies reach this stage at the same time, there could be a shortage.

Given the mix of strategies and opinions, further research into the strategy of retraining workers from other industries, such as computers, to biotechnology might prove fruitful. On the other hand, there may also be an opportunity to train people without prior manufacturing experience for biotech production. Both strategies offer new employment possibilities to a limited number of Massachusetts workers.

CONCLUSION

The analysis of skill requirements for low- and semi-skill jobs in biotech production suggests that while there seems to be variation in how firms are fulfilling employment needs, some patterns have also emerged. The implications of this analysis for low- and semi-skill labor include:

1. There are job opportunities in biotech for both low- and semi-skill labor.

2. These opportunities will increase as more firms mature in the next several years.

3. Because other options (i.e., hiring from outside the state, or hiring BS degreed workers for what are essentially low-skill jobs) are being ruled out, there appears to be a real opportunity to train a new workforce for biotech in Massachusetts. These workers will probably include some recent high school graduates.

5. There are probably opportunities in biotech for workers who have been laid off from production jobs in electronics or food industries, or who may be looking for a change.

6. Most firms do not have the resources nor infrastructure in place to train large numbers of workers. There may be a skills crunch in the near future if the demand for skilled labor grows quickly, and existing training programs do not adequately meet that demand.

Table 4.1

EDUCATIONAL LEVEL
Total Massachusetts Workforce vs. Biotech Workforce
(1990)

Highest Degree Attained	Percent
DEGREED	
Total MASS Workforce	33.1%
Biotech Workforce Sample	72.2%
NON-DEGREED	
Total MASS Workforce	66.9%
Biotech Workforce Sample	27.8%

Source: Current Population Survey, Bureau of Labor Statistics, March 1990
Mass. Biotech Sample, 4 firms, 1991

Table 4.2

HIGH VS LOW SKILL LABOR
in both Diagnostic and 3 Therapeutic Firms

DIAGNOSTIC

Highest Degree Attained	Percent
High Skill Jobs (require BS or more)	57.4%
Low Skill Jobs (require less than BS)	42.6%
TOTAL	100.0%

3 THERAPEUTIC FIRMS

Highest Degree Attained	Company A	Company B	Company C
High Skill Jobs (require BS or more)	78.8%	77.5%	67.2%
Low Skill Jobs (require less than BS)	21.2%	22.5%	32.8%
TOTAL	100.0%	100.0%	100.0%

Source: Case study data gathered from 4 firms, 1991
High skill = bachelor's + required
Low skill = less than bachelor's

Table 4.3

BIOTECH WORKFORCE BY MINIMUM DEGREE REQUIRED
Massachusetts: 1991

Job Descriptions	Minimum Degree PhD	BS	AA	HS	Starting Salary
PRODUCTION					
Director	X				$59,000
Fermentation					
Supervisor		X			$31,000
Reserach Associate		X			$27,000
Technician		X			$21,000
Assistant				X	$18,000
Purification					
Supervisor		X			$31,000
Research Associate		X			$27,000
Technician		X			$21,000
Assistant				X	$18,000
Aseptic Fill					
Supervisor		X			$31,000
Research Associate		X			$27,000
Technician		X			$21,000
Assistant				X	$18,000
Quality Control					
Supervisor		X			$32,000
Engineer		X			$32,000
Analyst		X			$25,000
Inspector				X	$21,000
Microbiology Supervisor		X			$32,000
Microbiologist		X			$24,000
Validation					
Supervisor		X			$57,000
Technician			X		$20,000
Quality Assurance					
Supervisor		X			$47,000
Documentation Specialist		X			$29,000
Technical Writer		X			$23,000
Documentation Clerk				X	$19,000

SOURCE: Bay State Skills Corporation, Biotech Directory 1991. Salaries are average estimates provided by MA firms.
Note: There are also a few non-degreed technical support positions.

Table 4.4

INCREASE IN NON-DEGREED LABOR
by Stage of Production Development
by date of company founding

SKILL LEVEL	R&D Company A (1989)	CLINICAL Company B (1981)	COMMERCIAL Company C (1981)
TOTAL EMPLOYMENT			
High Skill Jobs	91.7%	78.8%	67.2%
Low Skill Jobs	8.3%	21.2%	32.8%
	100.0%	100.0%	100.0%
PRODUCTION			
High Skill Jobs	93.5%	60.0%	37.8%
Low Skill Jobs	6.5%	40.0%	62.2%
	100.0%	100.0%	100.0%

Source: Case study data gathered from 3 MASS firms, 1991
High-skill = bachelor's degree + required
Low-skill = less than bachelor's

Chapter 5
Women & People of Color

INTRODUCTION & FINDINGS

In the previous chapter, I analyzed the question of who gets biotech jobs from the standpoint of skills. An important goal of progressive economic development is to enhance opportunities for underserved populations. So, in this chapter, I analyze the question of access from the standpoint of gender and race/ethnicity. No previous study of the Massachusetts' biotech industry has examined the labor force from this standpoint. It remains an important question for gauging how future industries will serve the special populations.

Diversity in the workforce has become a fact of life in the US. The composition of the US workforce is nearly half women and it is expected that in the next century, the majority of new entrants to the US workforce will be non-white. In Massachusetts, the trend towards racial diversity is occurring more slowly. Despite this larger trend, high tech industries remain largely white and mostly male at senior research and management positions (see High Tech Research Group, 1984).

In a case study of biotech in California in 1983, Ann Markusen noted that the female labor force in biotech was proportionate to all industries, and minorities constituted 21% of all biotech occupations. She thought the latter was probably inflated due to the classification of foreign nationals as minorities in the case study (Markusen, 1983). In my case study, I distinguish between US minorities and foreign nationals. However, I do not attempt to compare Massachusetts data with California data, because the California labor force is considerably more diverse racially and ethnically than the Massachusetts labor force.

The Major findings include:

1) Women occupy nearly half of the science positions in biotech firms in Massachusetts, which reflects science degrees awarded in the US.

2) Percentages in the sample of women in select occupations are close to percentages for same occupations for all the US.

3) Minority representation in biotech lags behind other industries, including the US drug industry.

4) Those minorities in the biotech workforce are mostly in low-skill areas, with a large number of Asian women in assembly work.

5) There are differences among firms in the female and racial/ethnic composition of the workforce, suggesting that some firms are more successful in recruiting.

6) Opportunities for minorities in biotech will be enhanced if more minorities are recruited for training programs and if companies adopt goals for hiring.

The analysis of women in the biotech labor force is presented first, and people of color second. Throughout the analysis, brief comparisons among firms are made, as are comparisons between Massachusetts biotech and the US drug industry, all US industries, and educational attainment in life sciences for women and people of color.

RESULTS

The following analysis is based on information gathered from four Massachusetts' biotech firms out of the original eleven interviewed for this project. While the case study approach limits one from generalizing about all biotech firms in the state, the results are still instructive. The sample probably inflates the presence of people of color in the labor force, because it includes the largest companies in Massachusetts. Larger firms tend to have more employment in production activities than small firms. Production jobs require a lower level of education than research jobs, and the pool of workers from which to hire for these jobs is more diverse as education requirements drop. It would be misleading to evaluate the younger companies whose main activity is research and not manufacturing. All of the firms in the sample were founded before 1982.

The analysis of access in the biotech workforce is based on a set of comparisons. The first comparison is between the case study data and all drug industries in the US (SIC 283, which includes biotechnology), to see if the Massachusetts female and minority employment levels in biotech are higher or lower than the national average for drug industries. Second, I match occupation data from the sample with US occupational information for all industries to see if women and minorities are present in certain occupations at higher or lower levels than for similar occupations for all US industries. The third comparison considers educational attainment to see what percentage of degrees in the life sciences are earned by women and by minorities.[1]

Women in the Biotech Labor Force

Women represent exactly half of the Massachusetts biotech labor force in the four case studies (see table 5.1). This figure is higher than the percentage of women in the total Massachusetts labor force (47.3%) for the same year, and higher than the percentage of women (44%)in the US drug industry (SIC 283) in 1988. The percentage of women in the workforce for each company in the sample ranges from a low of 41.5% to a high of 60.9% (see table 5.2).

While we cannot perform hypothesis tests because the sample is small and non-random, it is nonetheless tempting to try to explain the differences between firms. It would seem that the degree of the vertical integration, or whether a company was in the diagnostic or therapeutic market sector, would have little effect on how many women work in the company. However, these differences appear to be significant in the sample. The firm with the largest percentage of women in its workforce is the diagnostic firm. This same firm is also the most vertically integrated, because it is doing more commercial manufacturing than the others.

However, vertical integration does not seem to explain the difference between the therapeutic firms. Therapeutic 3 is less vertically integrated than therapeutic 1, but has a greater share of women in its workforce than therapeutic 1. Even though therapeutic 1 is the oldest and largest firm in the sample, it falls furthest below the mean. Therapeutic 1 is twice the size of

[1] The most recent data on education attainment was available for the national level only, with the exception of a new biotechnology certificate program in progress at three Massachusetts' junior colleges.

therapeutic 3, and has a much larger production capacity. Present data does not seem adequate to explain these differences.

Tables 5.3 and 5.4 compare occupation data for the biotech sample with all occupations for the nation. Women are represented in greater proportions in scientist occupations in our sample (50.6%) than they are nationally (39.7%). Women are also present in large proportion in technician occupations. One scientist, from a local firm, observed that:

> *I think you're going to see a lot of women in the labs. I think there's still all the barriers and all the old boy networks being formed when you start going up the ladder [out of the lab and into administration]... I would guess that the more academic organizations are much less tolerant of women.*

After examining the information about who earns life science degrees nationally, it is not surprising to see a high percentage of women in biotechnology. Women earned slightly less than half of all advanced degrees in the life sciences (including biology) during the 1986-87 school year.[2] Biology stands in stark contrast to engineering, where women earned only 13.2% percent of degrees during the same period. Likewise, of all electrical engineers in US firms, only 7.9% were women (BLS, 1989, Bulletin 2340, p.90).

At junior colleges during the 1986-87 school year, women earned 55% of the degrees awarded in life sciences nationwide. This spring (1991) in Massachusetts, three junior colleges will be awarding certificates in biotechnology for the first time. The three participating colleges have reported their enrollments to the Bay State Skills Corporation, who provided seed funds to these schools. Women represent almost 60% of the enrolled students (see table 5.6). If this year's graduating class is typical of future classes, then women will likely enter the production workforce in greater numbers in the future than at present.

---

[2] "Digest of Education Statistics," the National Center for Education Statistics, 1990.

People of Color in the Biotech Industry

People of color represent 9.2% of the workforce in the case studies,[3] of whom 4.2% were African-American and Latino. The most recent data (1988) for SIC 283 showed that the workforce in US drug industries included 14% minority, of whom 8.5% were African-Americans and 5.5% were people of Hispanic origin (see table 5.1). Data on Asians in the drug industry's workforce is not available. Biotech firms in the Massachusetts case studies lag far behind the US drug industries in terms of the racial and ethnic composition of their workforce.

We can also compare the Massachusetts case study data with the entire Massachusetts labor force. The Bureau of Labor Statistics (BLS) estimates that minorities[4] represent 6.1% of the total labor force in Massachusetts as of March 1991. If we exclude Asians from the biotech case study, then the percentage of African-Americans and Latinos in the Massachusetts biotech sample is 4.7% (see table 5.1), which is slightly lower than the statewide average. So by comparison with the national average for all drug industries, and the total Massachusetts labor force, we see that Massachusetts biotech workforce is considerably more homogenous.

There is a large difference among firms in the study. The diagnostic firm employed more minorities than the other three therapeutic firms together. In chapter 4, I reported that diagnostic firms hire more low- and semi-skill labor, which may account for the differences in the case studies. Furthermore, the diagnostic company in the sample is manufacturing products for commercial sale, while the therapeutic firms either license production or do not yet have products approved for sale. We can see from table 5.2 that the production workforce of the diagnostic company comprises nearly 70% of the company's total workforce[5], whereas production in the

---

[3] Because percentages hide real numbers, the reader should be reminded that the total number of minorities in this sample of four companies is less than 60.

[4] Note: BLS does not gather data for Asians, and there is some overlap in the counting of black and hispanic. So while 6.1% percent of the total Massachusetts' workforce is minority, it overcounts black and hispanic, and does not count Asians. A preliminary 1990 state census report estimates that Asians and Pacific Islanders comprise 2.4% of the state's population.

[5] Because the firm reported production and administration together as 'operations,' the estimate for production is high. Even if we eliminate all of the clerical and professional staff included in operations (several of whom probably do serve in a production capacity), the production estimate becomes 47% -- still well above the other firms.

other firms ranges from 15.2% to just under 37 percent. Forty percent of the production workforce is comprised of minorities in Diagnostic 1, the largest share of which is Asian women who work almost exclusively in assembly. Production is probably the area of activity in biotech where the greatest opportunity for diversifying the workforce lies.

There are also notable differences between the three therapeutic firms. In table 5.2 we see that Therapeutic 1 not only employs the smallest percentage of women, but also the smallest percentage of minorities, despite the fact that it is older and more vertically integrated in terms of production than the other two therapeutic firms. Of the three therapeutic firms, Therapeutic 1 is the only company without an affirmative action plan. Therapeutic 2 has a plan, and Therapeutic 3 is in the process of drawing up a plan. This finding suggests that developing a production capacity does not guarantee that the workforce will diversify. Company hiring goals and practices may also make a difference.

The reader should be warned that the number of minorities in certain occupations in the sample is far too small to allow conclusions to be drawn from it. However, indications about occupational access can be made. Table 5.6 excludes Asians from the count of minorities by occupation in the Massachusetts biotech sample, so that Massachusetts data can be compared with national occupation data, which also excludes Asians. The safest and most obvious conclusion from table 5.5 is that the diagnostic company shows the greatest diversity in its workforce by occupational level, while most of the therapeutic firms are more segmented.

Data on minorities earning advanced degrees in biology was not available, but the BLS reports that the percentage of blacks and hispanics who worked professionally as biological or life scientists in 1988 was 1.0% and 2.4% respectively (BLS, 1989, bulletin 2340). During the 1986-87 school year, minorities earned 26.8% of the associate degrees in life sciences, which was higher than the 16% rate of all associate degrees earned by minorities (see table 5.6). In Massachusetts' junior colleges, 10.5% of the students enrolled in biotech certificate programs are minorities, which is very close to the statewide population of minorities (estimated to be between 10.2% and

12.2% -- the first figure probably excludes some hispanics, the other probably double counts some hispanics).[6]

From chapter 4, we know that special training is required for semi-skill production jobs, so state programs will play a key role in helping minorities gain access to these jobs. Although the program is in its infancy, it is not too early to ask why two schools (University of Lowell and Massachusetts Bay Community College) succeeded in attracting students of color, and one (Middlesex Community College) failed to enroll a single student of color. The reason cannot be that there are no minorities living in the area served by Middlesex Community College. Lawrence, where nearly 42% of the population is of hispanic origin, is nearby.

While these programs may rely on students to come to them, schools should make a concerted effort to recruit from underserved populations. Further research into the colleges's recruitment goals and strategies, as well as student needs (such as transportation) might come up with valuable policy recommendations for ways to increase minority enrollment, as well as ensure that students are placed in firms. Schools and employers should work together to help graduates gain access to jobs in these firms. I was surprised during interviews to learn that some employers were not well informed about the existing training programs. Better outreach and coordination is needed to facilitate communication between schools, firms, employers, and students.

CONCLUSION

In answering the original question about *who gets biotech jobs?*, the preceding analysis of a Massachusetts biotech sample presents several major implications for women and people of color.

1. Commercial biotechnology is a promising field for women with science backgrounds. Women have accessed biotech laboratories in larger numbers than most science-based, private industries. This pattern reflects educational degrees granted in the life sciences.

[6] see Massachusetts Institute for Social and Economic Research, UMASS Amherst, 1991. Based on preliminary US Bureau of the Census data, subject to change before July 15, 1991.

As long as the number of women earning biology degrees continues to remain high, their presence in science professions in biotech firms should continue.

2. While women have gained access to the labs, they represent a smaller percentage of executive and managerial occupations in biotech than in all industries nationwide. This finding suggests there are stronger barriers to these occupations in biotech than elsewhere, and that affirmative action goals might help companies address this imbalance.

3. The minority workforce in biotech is minuscule at present. It lags behind both the national average for the drug industries, and the percentage of minorities in the total Massachusetts' workforce.

4. Opportunities for people of color to access biotech jobs will probably increase as companies develop manufacturing operations, where education requirements are lower.

5. The major barriers facing people of color are education requirements, access to training programs, and absence of hiring goals in biotech firms.

6. Given that a small percent of advanced life science degrees go to minorities, the greatest opportunities for expanding minority presence lie in low- and semi-skill jobs. Representation of minorities in semi-skill jobs will likely increase, if the number of minorities in the certificate programs at junior colleges increases. Likewise, the number of minorities in low-skill jobs may increase if targeted recruiting from high schools is done. However, companies that develop affirmative action plans are more likely to hire more people of color than firms that do not have such plans.

7. Other than efforts in Worcester and at Boston University, training programs do not exist in many key urban areas, like Roxbury. The feasibility of starting a training program at Roxbury Community College should be explored. However, given state budget cuts, community colleges may have to difficulty getting funding. Local biotech firms might be a source of support for providing or sharing expensive equipment.

Table 5.1

LABOR FORCE by gender, race/ethnicity
(in percent)

LABOR FORCE	US DRUG[1] (SIC 283)	ALL[2] MASS.	BIOTECH[3] SAMPLE
	---	(in percent)	---
GENDER			
Male	66.0	52.7	50.1
Female	44.0	47.3	49.9
RACE/ETHNICITY			
White	-	94.5	90.3
Black	8.5	3.3	3.4
Hispanic	5.5	2.8	1.3
Asian	-	-	5.0

[1] "Handbook of Labor Statistics," US Department of Labor, Bureau of Labor Statistics, 1989.

[2] Bureau of Labor Statistics, 1991. Note: There is some overlap between Black & Hispanic.

[3] Data comes from 4 Mass. biotech firms, 1991.

Table 5.2

Massachusetts Biotech Workforce
Race, Ethnicity & Gender
Sample of 4 Firms, 1991

AREA OF ACTIVITY	Percent DIAG 1	THERAP 1	THERAP 2	THERAP 3	ALL FIRMS 4
R&D (% of Total Emp.)	30.4	38.6	31.3	53.0	38.6
Women (% of R&D)	54.3	50.5	61.9	28.6	46.6
Minorities (% of R&D)	2.9	2.2	4.8	7.1	4.2
PRODUCTION (% of Total Emp.)	69.6	36.9	33.6	15.2	37.6
Women (% of Prod.)	63.7	28.7	51.1	45.0	46.6
Minorities (% of Prod.)	40.0	2.3	6.7	10.0	16.8
ADMIN (% of Total Emp.)		24.6	22.4	30.3	20.7
Women (% of Admin.)	*	46.6	60.0	60.0	53.9
Minorities (% of Admin.)		6.9	0.0	0.0	3.1
SALES (% of Total Emp.)			12.7	1.5	3.1
Women (% of Sales)	(see note)		58.8	50.0	57.9
Minorities (% of Sales)			11.8	0.0	10.5
ALL DEPARTMENTS	100	100	100	100	100
Women	60.9	41.5	57.5	48.5	50.1
Minorities	28.7	3.4	6.7	5.3	9.2
Foreign Nationals	-	3.0	1.5	2.3	1.9

Source: Case Study 4 Massachusetts Biotech Firms, 1991.
* included in production
Note: sales are carried out by parent and alliance partners respectively.

Table 5.3

Women in Biotech Workforce by Occupation
MASS Biotech Sample
(% of total occupation)

	Women				
OCCUPATION	Therap. Firm 1	Therap. Firm 2	Therap. Firm 3	Diag. Firm 4	4 Firm AVERAGE
Executive, managerial, supervisory	45.0%	38.7%	24.7%	50.0%	39.6%
Scientist (biology)	57.4%	41.3%	50.5%	53.1%	50.6%
Biological technician	44.4%	50.0%	14.3%	50.0%	39.7%
Administrative support, including clerical	93.3%	100%	100%	75.0%	92.1%
Assemblers	60.0%	50.0%	20.0%	76.5%	51.6%
Production inspectors, testers, samplers & weighers	16.7%	100%	66.7%	80.0%	65.8%

Source: Mass. Biotech sample, 1991.

Table 5.4

EMPLOYED CIVILIANS IN US BY DETAILED OCCUPATION,
Sex, and Race/Ethnicity

OCCUPATION	Total Employed (000s)	Percent of Total		
		Women	Black	Hispanic Origin
Executive, administrative, & managerial	14,216	39.3	5.6	4
Prof. specialty: Biological & life sciences	75	39.7	1	2.4
Biological technicians	55	42.5	8.2	5.1
Administrative support, including clerical	18,264	80.1	11.3	6.5
Machine operators, assorted materials	2,680	33.5	15.6	13.9
Assemblers	1,141	44.2	14.7	13
Prod. inspectors, testers samplers & weighers	849	51.6	13.9	12.1
Freight, stock and material handlers	1,756	17.5	15.8	8.7

SOURCE: "Handbook of Labor Statistics," US Dept. of Labor, Bureau of Labor Statistics, 1989

Table 5.5

MASSACHUSETTS BIOTECH TRAINING PROGRAMS
Certificate Degree
1990-91 (First Year)

Program (location)	# students	percent female	minority (total)	Black	Asian	Hispanic
Mass. Bay (Wellesley)	36	52.8	16.7	8.3	8.3	0.0
Middlesex (Bedford)	20	65.0	0.0	0.0	0.0	0.0
U.Lowell (Lowell)	20	60.0	10.0	0.0	5.0	5.0
TOTAL	76	57.9	10.5	3.9	5.3	1.3

Source: Bay State Skills Corporation, 1991.
Note: These programs train people for semi-skill positions. The programs have prerequisites that screen for math/science background.

Table 5.6

MINORITIES IN BIOTECH WORKFORCE,
by Occupation
(% of total)

SELECT OCCUPATIONS	Minorities				
	Therap. Firm 1	Therap. Firm 2	Therap. Firm 3	Therap. Firm 4	4 Firm AVERAGE
Exec., manager, supervi'y	0.0%	0.0%	5.5%	6.3%	2.9%
Scientist (biology)	0.0%	4.8%	2.2%	0.0%	1.7%
Biological technician	22.2%	0.0%	22.2%	12.5%	14.2%
Administrative support, including clerical	0.0%	0.0%	0.0%	25.0%	6.3%
Assemblers	0.0%	0.0%	0.0%	8.8%	2.2%
Prod. inspectors, testers, samplers & weighers	0.0%	0.0%	0.0%	20.0%	5.0%

Source: Massachusetts Biotech sample, 1991.
Minorities = both black and hispanic.
Asians excluded because BLS does not offer comparison data.

Chapter 6

Analysis of Job Quality

INTRODUCTION

Chapter 6 brings to a close the list of questions originally raised about biotech production jobs. Chapter 3 answered the question: how many production jobs are created as the production process for a product matures? Chapter 4 and 5 answered the question: who gets production jobs, from the standpoints of skill, gender and race/ethnicity. Chapter 6 analyzes case study material and secondary material to answer the question: are these good jobs?

Job quality can be measured in many ways. For purposes of this chapter, I have gathered information about

- wages and health benefits,
- opportunities for advancement, and
- worker safety.

The last question is raised because there has been considerable controversy surrounding recombinant DNA research, in particular, the fear of exposure to genetically altered microbes.

Significant findings regarding job quality include:

1) Wages are comparable, but slightly lower than the average for all production workers in manufacturing industries in Massachusetts. Full health coverage is provided by the overwhelming majority of companies.

2) Opportunities for advancement are restricted by education, and potentially represent a real drawback to employees hoping to make a career in biotechnology. There is evidence of a diversity of opinions among firms about the level of advancement that a high school person can expect to attain. However, firms are presently encouraging and supporting employees to continue their education in order to expand their opportunities for advancement.

3) There is a danger that workers will be exposed to a number of biological, product, and process hazards, but generally, the industry takes extra special precautions to prevent accidents.

SALARY/WAGES & BENEFITS

The recent Feinstein survey (1990) reported that the average salary among Massachusetts biotech firms was $30,700. However, one would expect the average salary to be high, given the large number of people working in research who have advanced college degrees. The high average wage for all workers may hide the fact that the distribution of wages among various occupations is wide. Biotech production workers are probably not getting rich.

Other recent surveys reported a sample of starting salaries. The Massachusetts Board of Higher Education Regents (HE) survey reported that people with an Associates degree could expect to earn between $18,500 and $24,000 (with three years experience), and workers with a bachelor of science (BS) could earn between $22,000 to $28,000 (with three years experience). However, so far, surveys have ignored salaries paid to low-skill workers in biotech. From chapter 3, we know that there are potentially more low-skill production jobs in a mature biotech plant than semi- or high-skill jobs. Surveys also failed to provide a realistic estimate of the average production salary in biotech, so that we can compare it to the average of other industries.

Because biotech production includes some highly educated workers, we can arrive at an estimate of the average production salary for non-degreed workers by excluding those positions for which a bachelor's degree (or more) is required (see table 6.1). From a private industry source, we estimate the average annual salary for Massachusetts biotech production jobs, not usually requiring a college degree, in 1990 to be $22,235.[1] The annual average salary for all production occupations in manufacturing industries in Massachusetts in 1990 is

[1] This source is based on an unpublished, annual industry survey of biotech firms across the nation. The estimate for Massachusetts is based on information supplied by Massachusetts companies.

estimated to be $24,106.[2] Thus, on average, non-degreed biotech production workers earn $1,871 less than production workers in all Massachusetts manufacturing industries. If we had included all biotech production jobs (degreed and non-degreed) in our estimate, the average salary would be $37,227.

We can also compare Massachusetts biotech hourly wage to the national hourly wage for all biotech firms (see table 6.2). The US Department of Commerce estimates that the hourly wage for biotech therapeutic firms (SIC 2836) was $9.25 in 1990, while it was $11.70 in diagnostics (SIC 2835). We can take the average of SIC 2835 and 2836, which is $10.48 and compare to Massachusetts biotech, which is $10.51.[3] The average Massachusetts' biotech wage appears to be close to the national average (when we combine 2835 & 2836), but is considerably lower than the national average for pharmaceutical preparations (SIC 2834, $13.58), medicinals and botanicals (SIC 2833, $16.82), and all drugs (SIC 283, $12.95).

One explanation for the difference between biotech firms and other drug industries may be that biotech firms are young and still largely unprofitable. Feinstein reports that only 33% of the companies in the Massachusetts sample showed a profit, and another 10% had reached break-even (1990: p.29). Once companies become profitable, salaries may begin to rise. The same phenomenon probably explains why diagnostics pay more on average, because more diagnostics are profitable than therapeutics. Finally, approximately half of the established pharmaceutical and chemical industry is unionized, which tends to raise wages. Local biotech firms are not unionized. One firm was adamant about remaining non-union:

> *We stay clear away from union people. We just don't want that here. The first time someone doesn't like something, we don't want them turning to a union. We'd rather they turn to us and say help us solve it. It's a real concern. We live with some fear of that, so we're doing everything we can to avoid it.*

---

[2] This figure was arrived at by taking the annual average hourly wage for production occupations in manufacturing industries in Massachusetts in 1990, which was $11.39 and multiplying it, first by the average hours worked per week, which was 40.7, and secondly by 52 weeks. The first two figures come from the Massachusetts Department of Employment & Training.

[3] This figure was arrived at by dividing $22,235 by 52 weeks, and 40.7 -- the average hours worked by production workers in Massachusetts manufacturing industries in 1990.

While we see that there are differences between degreed and non-degreed salaries in biotech production, likewise there is a substantial difference in salaries within non-degreed. On average, a person with semi-skill training in biotech in 1990 could expect to earn $5,605 more than a person in a low-skill position (see table 6.1). The average salary for all semi-skilled labor in biotech was $24,300 in 1990, compared to $18,695 for all low-skilled labor. According to a private industry survey, the bottom salary for a low-skill, entry level job, such as a 'tech I' or 'assembler,' was $13,500 (or $6.50/hour), and the high was $24,232 ($11.45/hour) -- nearly twice the low! The most probable explanation for this variation is that many firms say they fill entry level positions with BS degree holders, whom they must pay a higher salary (see chapter 4 for a discussion of hiring strategies).

Just because low-skill and semi-skill salaries in biotech are lower than for all manufacturing in Massachusetts, it does not necessarily mean that these jobs are bad. They provide full health benefits. All of the eleven firms interviewed for this study provide full coverage, and most offer worker equity -- not typically available in traditional industries. Equity may one day be worth a great deal more than was paid for it, and may also may give workers pride and a sense of ownership for the firm's success.

ADVANCEMENT

I argued in chapter 4 that education attainment, more than experience, delineates job levels in biotech. The implication is that a worker must gain further education before advancing in the company. In traditional industries, an ambitious employee *might* rise from the shop floor to become a manager. Experience and competence, more than education, were the tickets to advancement. The same cannot be said for biotechnology firms. The implication for low- and semi-skill labor is that they will have to return to school for a degree in order to advance, or face being stuck in one or two positions within the firm, or look for work in another industry. The implication for employers is that they may have to devise ways to prevent employees from stagnating and becoming frustrated enough to leave.

Surveys provided anecdotal information about advancement in biotech firms. The survey by the Economic Development Industrial Corporation (EDIC) of Boston, reports that there are some cases where a non-lab job might lead to a lab job. It did not specify which

kind of employee (whether high school or bachelor's) could advance. Furthermore, low-skill, lab jobs in biotech can be dead-end jobs as much as non-lab jobs. The interviews with firms provide a rich source of information about opportunities and limits to advancement, as well as highlighting some interesting differences between firms. At the time of this research, most firms did not have personnel plans that delineated horizontal or vertical promotions for employees, although one firm was in the process of developing a plan at the time of this writing.

There are two types of advancement in biotech, as in most industries. One path is to move upward, and the other is to move across from one area of production to another. While there is variation in the advancement paths described by the firms, opportunities for advancement generally seem to be greater in diagnostic firms, where education requirements are more flexible. Perhaps this difference is due to the fact that these firms are less heavily regulated than therapeutic firms giving them more flexibility to move around their employees. The most common advancement model pertains to therapeutic firms.

VERTICAL & HORIZONTAL ADVANCEMENT

The generic employment structure for the production area of a therapeutic firm includes five levels -- from operators, on the bottom, to the vice-president at the top (see table 6.3). Levels 4 and 5 repeat themselves for each process area: cell culture and fermentation, purification and aseptic fill, and quality control. Generally, a high school degree is the minimum requirement for levels 4 and 5, but a BS is required for the top three.

Of the three largest therapeutic firms in my study, personnel executives from two of them said there were possibilities for someone with a high school degree to advance to a supervisory level (level 2) without additional education, but not much beyond.

> *[From] the very bottom level, the operator, could probably move up to become a supervisor, which is the next tier ... Someone with only a high school degree is probably not going to work their way up the corporate ladder to become the VP of manufacturing -- no matter how good they are -- because they won't have the theoretical base.*

Only one major employer of a therapeutic company confidently said that an entry-level person could rise higher to become the head of supervisors. He offered the possibility that someone with a high school degree, if ambitious and patient, might even rise to management levels within production.

> [Biotech is] *not unlike other mature industries. People [with a high school degree] can come in and work their way up to a management position -- even beyond the first level supervisory position. That's going to happen over a span of time. People can progress through various stages of skill and, eventually, having demonstrated management and supervisory ability, can be considered and in fact become supervisors in a management position. From there, it's just a question of how good they are. They could potentially move laterally over to some other position in the company. People coming and making a career in manufacturing tend to stay in those kinds of jobs. After supervisory level, you tend to see people with bachelor's degrees.*

The plant manager of this same company agreed with this assessment. He mentioned several high school graduates he has working in the plant now, who have been training and are picking up semi-skill jobs quickly. Their plant manager in Europe is a high school graduate with 30 years of experience, and *"he knows that plant inside and out."*

The second type of advancement involves moving horizontally, from one process area to another. For example, a person working on the assembly line might be asked to move across to aseptic fill, cell culture/fermentation, or quality control, all of which require different skills than assembly. Lateral movement occurs frequently in one of the diagnostic firms in the sample. People can move from assembly to cell culture and then to quality control. While similar moves are possible in therapeutic companies, most companies in the study did not describe them as common occurrences. However, it may hold future potential, as employers find ways to make it work.

> *It's difficult for somebody to move from packaging into formulation without experience. We have an effort underway to do more cross training, but it's hard. We've been so pressured to turn out products. It's easiest and most expeditious to get the people who have already worked on something to do it again. So the cross training is a nice idea, but it still needs to happen.*

WORKER STAGNATION

The danger in not having mobility is that people begin to feel that they are stagnating. Without opportunities to learn new skills and advance, employees begin to get discouraged, and their productivity may decrease or they may chose to leave. Employers would rather not have to pay the costs associated with having a high turn-over rate. Production needs to have stability and continuity, say plant managers. Worker retention is a goal of theirs. However, the problems with mobility have not been addressed by the industry yet.

> *I am concerned about the lack of mobility for folks within the production area to really move up... It's difficult to look to moving up in production when you know that the boss has a degree that you don't have... We have a tuition reimbursement program, and we really try to sell it to people in production...*

Two other companies mentioned the problem of little advancement. They said it affects BS degree holders as well as non-degreed workers. The problem is becoming widely recognized in the industry.

SAFETY

Biotechnology has attracted as much attention for its potentially harmful environmental and health effects, as for its beneficial effects. Since the beginning, micro-biologists have taken fairly unprecedented steps to organize themselves to prevent any harmful effects of their research using recombinant technologies starting with the Asilomar conference in the late 1960s. They wanted to avoid repeating the history of atomic physicists in the 1940s, whose scientific research was carried out in secret and was eventually put to destructive uses.

Today, the commercial biotechnology industry has a strong safety record due in part to efforts by scientists, through the National Institutes of Health (NIH), to develop and promulgate safety guidelines for recombinant DNA research. However, a recent study of the occupational safety in biotech remarked that the *"informal, overlapping web of mostly voluntary safety procedures... is hardly a 'safety net,' yet major exposures and flagrant practices are hardly the norm in biotechnology"* (Ducatman et al, 1991, preface).

While there is self-policing in addition to federal oversight, those people working in the labs and plants appear to take safety precautions seriously. There are strict standards regarding facility design and management of the production process. As the level of risk assessment goes up, requirements for containment and safety go up. The kinds of host organisms used in biotechnology are such that there is a very small chance that they would survive outside the lab. However, despite these requirements, workers are still in danger of being exposed to a number of hazards.

The major categories of biohazards are (for a detailed list, see table 6.4):

1) *biological hazards*: workers may be exposed to pathogenic organisms, viruses, and carcinogenic mammalian cells. Besides danger of infection, workers may experience allergic and immuno- responses.

2) *production hazards*: workers will likely handle raw materials used in production, including radioactive materials (e.g. radioisotopes). Overexposure to these materials is a risk.

3) *process hazards*: workers work with and around corrosive chemicals and flammable solvents, which pose risks. In addition, work conditions may cause injury or stress, due to excessive noise, temperature extremes, slippery surfaces, and mechanical problems (eg. projectiles).

Production workers in the fermentation and purification areas *"encounter risks similar to those of workers in pharmaceutical and chemical industries, that is, exposure to the final physiologically active products. Exposures to even minute quantities of certain physiologically active products may cause medically significant side-effects"* (Goldman, see Ducatman, et.al. 1991, p.215). But there are two important outcomes due to the differences between pharmaceutical industries and biotechnology products. The first is that fewer workers are likely to be exposed, because biotechnology products are more capital intensive. It takes fewer people to produce a product. However, the second difference is that biotechnology products are purer and more concentrated, and therefore, more dangerous. So, workers are at risk of being exposed to more dangerous products.

Other workplace hazards include animal handling which may lead to bites or scratches, or infection by transmittable diseases. The latter may include HIV virus. Finally, there are physical stresses resulting from repetitive motions and heavy lifting due to inadequately designed work spaces and work routines. However, these are workplace hazards common to many industries.

Genetics Institute, Inc., located in Cambridge and one of the nations largest DBF, participated in a study of workplace injuries between 1984-89. More than 80% of the accidents were reported due to lacerations, punctures, strains, and burns (see table 6.5a). Most of job-loss time was accounted for by back injuries and strains (see table 6.5b)

Industry hazards can be controlled through a variety of strategies. The first is to substitute non- or less- hazardous materials for the hazardous materials. The second is to engineer solutions that reduce or eliminate the hazards. Third, hazards may be controlled through proper facility and personnel safety procedures. Medical surveillance of employees based on a plan that accounts for the specific types of hazards for each work activity is strongly recommended (Goldman, see Ducatman, et.al. 1991, p.209).

In general, occupational health experts say that while biotech presents potentially serious effects, they are no worse than those encountered in the past. *"Most commercial and academic laboratories are making efforts at containment and most use safety professionals routinely. It is reasonable to hope that the biotechnology revolution will have markedly fewer victims than past technological revolutions"* (Ducatman et al, 1991, preface).

CONCLUSION

The major findings about job quality are that:

1) Average annual Massachusetts biotech manufacturing salary is the same as the national average for all biotech (SIC 2835 & 2836), but is lower than the annual average for all manufacturing in Massachusetts. However, most of the new biotech companies are not yet profitable. And many firms also offer company equity at reduced prices.

2) There is considerable variation in salaries between low- and semi-skill, as well as within skill areas. This variation is probably due to the mix of degreed and non-degreed labor in the same job descriptions.

3) Full health benefits are typically provided.

4) Opportunities for advancement exist, but are quite limited for non-degreed labor. However, there is a difference of opinion about how limiting a high school degree is for someone in manufacturing operations who is talented and ambitious.

Table 6.1

AVERAGE ANNUAL SALARIES
for Biotech Production Jobs
Boston (1990)

ALL BIOTECH PRODUCTION (degreed & non-degreed)	$37,227
All Semi-skill (1-3 years college)	$24,300
All Low-skill (high school)	$18,695
All non-degreed (semi + low-skill)	$22,235
ALL MANUF'G/MASS (1990) *	$24,106

SOURCE: Private Industry Survey, 1990
* Massachusetts Department of Employment & Training, includes production jobs only.

Table 6.1

US Trends and Forecasts in Biotech & Other High Tech Industries
AVERAGE HOURLY EARNINGS IN PRODUCTION
(dollars)

EARNINGS	1987	1988	1989	1990	1991	Percent Change 1987-88	1988-89	1989-90	1990-91
Average hourly earnings ($)	12.22	12.73	12.82	12.95	-	4.2%	0.7%	1.0%	-
2833 Medicinals & botanicals	15.32	16.09	16.37	16.82	-	5.0%	1.7%	2.7%	-
2834 Pharmaceutical preps	12.42	12.98	13.25	13.58	-	4.5%	2.1%	2.5%	-
2835 Diagnostic substances	10.74	10.99	11.25	11.7	-	2.3%	2.4%	4.0%	-
2836 Bio prod ex diagnostic	8.87	9.02	9.16	9.25	-	1.7%	1.6%	1.0%	-
3571, -2, -5, -7 Computers & Peripherals	10.47	10.75	11.16	11.45	-	2.7%	3.8%	2.6%	-
367 Electronic Components (including Semiconducters)	9.32	9.99	-	-	-	7.2%	-	-	-

SOURCE: U.S. Department of Commerce: Bureau of the Census; International Trade Administration (ITA). Estimates and Forecasts by ITA
1988 Advance data from the 1988 Annual Survey of Manufactures.
1989 Estimate
1990 Estimate
1991 Forecast
Trade Administration (ITA). Estimates and Forecasts by ITA

TABLE 6.3

VERTICAL ADVANCEMENT IN TYPICAL THERAPEUTIC FIRMS
by level and degree required

level 1 (BS, MS preferred) Vice President

The top of the production pyramid is the vice-president of Manufacturing/Operations, who directs planning and determines budgets, hiring policies, and programs.

level 2 (BS) Manager or Director

This person overseas the section supervisor, directs manufacturing operations, and manages facilities and work schedules.

level 3 (BS) Head Supervisor

All supervisors in level 4 report to the head supervisor, who coordinates each process area and its staff.

level 4 (HS + experience) Supervisors

Each 'supervisor' manages a small team of operators for one of several process areas (fermentation, separation, purification, aeseptic fill, and assembly).

level 5 (HS) Operators or technicians

The bottom of the employment ladder is the 'operator' -- or manufacturing assistant -- who is usually part of a small team of operators. This person assists manufacturing, including weighing raw materials, preparing media, operating machinery, taking measurements, maintaining GMP records, testing batches, and packaging final products.

Table 6.4

POTENTIAL HAZARDS IN THE WORKPLACE:
Biomedical/Biotechnology

TYPES OF HAZARD	EXAMPLES	POTENTIAL HEALTH EFFECTS
Biological Material	Blood, viruses, and bacteria genetically engineered organisms	Laboratory-acquired infections such as: tuberculosis
Mutagens and carcinogens	Alkylating agents, ethidiun bromide	Increased risk of cancer, reproductive system toxcity
Solvents/ reagents	Phenol, chloroform methanol, zylenexylene	Headache, dizziness, skin rash, mucous membrane irritation
Acids and bases	Sulfuric acid, hydrochloric acid, Sodium Hydroxide	Skin and eye burns
Gels	Acrylamide monomer	Neurotoxcity
Allergens	Piperizine, hydrazine	Nasal congestion skin rash, asthma
Chemicals used in special experiments	Cyanide & phosgene	Cyanide poisoning, pulmonary edema
Radiation	Radioisotopes	Increased risk of cancer, reproductive system toxcity
Lifting	Materials handling	Acute muscle strain chronic back pain
Repetitive Motion	Twisting caps	Tendonitis
Electrical	High voltage experiments	Electric shock

SOURCE: The Occupational & Environmental Health Center at the Cambridge, MA Hospital, 1988

Table 6.5 (a)

BIOTECH WORKPLACE INJURY RECORD
By Type of Injury, and Percentage of Days Lost
from Genetics Institute, Inc., Cambridge, MA
(1984-89)

Type of Injury					
Lacerations Punctures	Strains	Back Injury	Thermal Burns	Chemical Burns	Other
41.0%	18.0%	14.0%	11.0%	60.0%	10.0%

Table 6.5 (a)

Type of Injury		
Back Injury	Strains	Other
93.0%	60.0%	10.0%

SOURCE: "The Biotechnology Industry - Occupational Medicine" by Ducatman, et al. 1991

Chapter 7

Conclusions & Recommendations

We cannot conclude from this research that biotech is, or is not, good for Massachusetts. To make a broad statement about the industry would require examining more topics than labor. Creation of, access to, and quality of jobs for low- and semi-skill labor are one set of considerations among many. Other issues for consideration might include other benefits, such as tax revenues, and diversification of the economy, and jobs for high-skill labor. Negative impacts should be considered as well, such as potential environmental costs. However, the reader *should* draw implications from the research about the expectations and challenges facing economic development strategies based on biotech.

GENERAL CONCLUSIONS

In Chapter 2, I launched this study with a discussion about worldwide economic competition and the importance given by economic development planners to the set of US industries we call high tech. The reason high tech industries are favored by most states is because we think of them as innovative, competitive, and high growth. Innovation is necessary to be competitive in today's world economy. If industries are competitive, then we expect them to grow rapidly and provide public benefits, among which is employment.

However, my research into Massachusetts biotech suggests that these expectations may be overly simplistic. State government and local communities should be better informed about the particular characteristics of biotech industries, and should be more realistic in planning for biotechnology. In the following pages, I will address the important lessons learned from the research, which are:

1. High tech industries are different from each other. Some industries employ lots of people, while others do not. We must learn to distinguish among high tech industries.

2. Likewise, not all biotech industries have the same economic and employment outcomes. We must consider the differences among biotech industries.

3. Manufacturing matters in biotechnology (as in high technology), if jobs are an important policy goal. Innovation is necessary, but not sufficient to generate employment for lots of people. Careful economic development planning must include a strategy for manufacturing.

4. Having a skilled manufacturing workforce is a significant advantage in attracting, retaining, and developing high tech manufacturing, such as biotechnology.

Biotechnology industries resemble other high tech industries in that they employ a larger percentage of scientists than the manufacturing average. They are also highly innovative and competitive industries. However, biotech is different from other high tech sectors, such as computers. Biotech manufacturing is less labor intensive than the manufacturing of computers. Part of the explanation for this is that much of the work in biotech processes is done by plant or mammalian cells rather than by employees. Another reason is that the final product in biotech is a vial, or tablet, or test kit -- which has fewer pieces than a computer. Thus, the first lesson of this research is that *not all high tech industries have the same economic and employment outcomes.*

Economic development planners and communities should not expect the same benefits from different high tech industries. When planning for economic development, they should be clear about which problems they hope to address through industry development, and be realistic about which public benefits can be expected. For example, it would be foolish to expect unemployment problems to be solved by throwing support behind biotech. New jobs may be created by biotech, but not in large enough numbers to relieve current levels of unemployment (which are estimated to be around 9.0% in the first quarter of 1991 in Massachusetts). On the other hand, if enhancing revenues and diversifying the local economy are goals, then biotech should be able to meet these expectations.

The second lesson of the research is that *not all biotech industries have the same economic and employment outcomes.* Biotechnology includes industries that are making products for diagnosis and treatment of human and animal health, food and agriculture,

environment, and supplies. This study mostly concentrated primarily on the two largest biotech market segments: therapeutics (drugs & vaccines) and diagnostics (diagnostic test kits).[1]

I concluded that there are significant employment differences between therapeutic and diagnostic companies. Diagnostic products mature quickly and employ more low- than semi-skill labor, whereas therapeutic products develop slowly, and employ a mix of low- and semi-skill labor, but may eventually employ large numbers of people depending on product characteristics and markets. Company goals may also impact employment growth. Some companies may pursue the research boutique strategy and not attempt to develop manufacturing capacities, whereas others will work to become fully integrated.

The implication of this finding is that not only must communities distinguish among high tech industries, but they must also distinguish among biotech market segments. Economic development planning should weigh these differences in light of employment needs and workforce strengths.

Throughout, I have tried to emphasize that *manufacturing is as important in successful biotech economic development as innovation*, and that efforts must be made to plan for manufacturing. There are more total jobs and more jobs for the people who need them most in biotech manufacturing than in research and development. Opportunities for minorities to access biotech jobs are greater in manufacturing also. Another argument for the importance of manufacturing in high tech industries has been made by Cohen and Zysman (1987), who say that high-wage service jobs develop as a result of manufacturing. *"Lose manufacturing and you will lose -- not develop -- high-wage service jobs."*

While strategies to support research, technology development and transfer, and new company start-ups are critical for developing a biotechnology presence, it is not sufficient to ensure that full economic benefits from the industry will be enjoyed. Special efforts must be made to plan for the particular needs that companies have when they begin or expand

---

[1]. The 1991 Ernst & Young biotech survey estimated that therapeutics and diagnostics represents 63% of the total biotech market.

manufacturing. For specific suggestions, see the section below on policy recommendations concerning manufacturing.

The final lesson underscores a point that is being made more and more frequently. *A skilled workforce (in this case, a manufacturing workforce, not just an R&D workforce) is vital to capturing competitive industries, such as biotech.* The US has lost many industries to foreign competition over the last several decades, but, so far, retains competitive advantages in recent technological innovations, including biotech. Whether we can retain manufacturing depends in large part on how well we develop the skills of our workforce.

Biotech companies want to hire a mix of entry-level workers -- some workers need to have basic algebra and English skills, while others need to have special familiarity with laboratory equipment and manufacturing techniques. However, a national study on education found that between 1986-88 only 6% of 17 year old students demonstrated the ability to solve multi-step problems and use basic algebra, and only 8% showed the ability to draw conclusions and infer relationships using scientific knowledge.[2] Investing in the education and training of America's workers may be the single most important priority for national and state governments and private industry. This finding adds weight to the arguments being made presently against further cuts in the Massachusetts education budget, and goes further to argue that we should be renewing the public commitment to invest in education at all levels.

POLICY RECOMMENDATIONS

The following policy recommendations are based on the findings of this study. They are organized and presented according to the four topic areas discussed in chapters 3 to 6: growth, skills, access, and quality. Chapter 3 included the study of job creation for low- and semi-skilled labor in biotech manufacturing. Chapter 4 examined the skill and education requirements for these manufacturing jobs. Chapter 5 evaluated job access from the standpoint of participation of women and minorities in the workforce. Finally, chapter 6

[2] The 1990 National Assessment of Educational Progress, reported in the "Economic Report of the President" transmitted to Congress in February, 1991.

considered wages and benefits, opportunities for advancement, and worker safety as indicators of job quality.

GROWTH

Massachusetts should be more realistic in assessing employment outcomes from biotechnology. While the state needs positive news at present, it does little good to raise false expectations about the industry's prospects. If the sober forecast of minor job growth proves to be an underestimate, then Massachusetts can consider itself fortunate.

Timing is also important. We know from the research that hiring and manufacturing location decisions occur during scale-up. This finding means that there is a window of opportunity during which time steps must be taken to meet long-term labor and space needs of biotech companies. Knowing this timetable can help planners work efficiently and effectively to maximize the competitive resources of their area to enhance opportunities for biotech manufacturing.

The time for Massachusetts to act on manufacturing is now, because many companies will decide where to build manufacturing plants during the next two years. Company spokespeople say that Massachusetts has not shown as much willingness as other states to support manufacturing. As a result, many companies are considering manufacturing sites outside the state.

I am not prepared to argue that Massachusetts should provide free land, favorable leases, and tax advantages without a more thorough analysis of the costs and benefits of doing so. Nor am I convinced that Massachusetts can afford to compete with other states on these grounds. However, there are less costly and more efficient ways for Massachusetts to improve its competitive advantage.

I would recommend the state consider two major changes to retain manufacturing. The first includes developing a comprehensive and consistent regulatory framework for biotech manufacturing based on National Institutes of Health (NIH) guidelines. This change

will give companies a predictable environment on which to base future plans without worrying that regulations will change dramatically from place to place or over time. It would also lend protection and stability to towns and cities who may host these facilities.

The second recommendation would be to designate someone at the state to coordinate the permitting process for biotech manufacturing. Currently, companies planning to expand in, or enter Massachusetts have to sort through a complex regulatory system involving several agencies at different levels of government. I heard numerous complaints from firms that the permitting process in Massachusetts is disjointed and inefficient. Coordination would simplify the process and make it appear more friendly to companies.

Besides regulatory and permitting changes, there are broader and more challenging issues to which industry representatives addressed themselves. Nearly every executive spoke about the need to resolve the state's fiscal crisis. Another problem frequently mentioned was the high cost of housing, which makes it difficult for firms to recruit people from outside the state.

State government is not the only level of government that can plan for biotech development. Cities and towns can be players too. Worcester provides a successful example. While Worcester has certain key advantages, including universities and a medical school, it has also developed and implemented a plan that put all the major components that are attractive to biotech firms in place. They built a biotech industrial park, adopted NIH guidelines concerning rDNA research as their regulatory framework, and aggressively recruited companies. Certificate programs to train semi-skill labor for biotech are also being planned by local colleges.

SKILLS

Massachusetts must give greater consideration to the education and training needs of its labor force. The state already has a large, high-skilled labor force. Scientists generally like living here because of the universities and cultural amenities. If Massachusetts can develop a

pool of trained semi-skill labor, and develop ways for firms to easily access low-skill labor coming out of high schools, then firms are more likely to consider expanding inside the state.

Workforce training should be the shared responsibility of the biotech industry, state government, and the public school system. Training efforts started by Bay State Skills Corporation and three local junior colleges provide a good role model for future cooperation between these entities. However, the certificate programs in biotech must have a secure source of funding to meet the growing demand for semi-skilled labor. Because these are hard times for state government to find the resources for worthwhile projects, the biotech industry must look inward to see if it can help finance and support external training programs.

According to employers, there may be a shortage of semi-skilled labor starting some time in the next two years. As that need increases, some firms may become more willing to develop internal training, or they may prefer to fund external training to meet their demand (as they are currently doing to some extent). The state should also consider expanding training programs to other colleges in the Boston-Cambridge area, in hopes of opening up job opportunities to people of color living in the City.

Better communication is needed too. I was surprised to learn during the interviews that some employers were not aware, nor always well informed about the junior college biotech training programs. The 1990 Economic Development Industrial Corporation (EDIC) survey also found a lack of awareness among many firms about training programs. And it was not just the newest and smallest firms which were unaware. The essential information that firms need to know includes the names of the training schools, program content, number of graduates, and how to contact them.

Most of the training efforts, so far, have focused on people at the associates degree level, to the exclusion of high school students. The biotechnology industry association (The Massachusetts Biotech Council) is making an effort to expand teacher and student awareness of biotechnology as a science and as a career path. However, there may be more direct ways to target those students, who have taken at least one laboratory science course but are not planning to attend college, for entry-level jobs in biotech. One approach to making this

connection more explicit might be to ask companies to take on student interns for a term or for the summer.

ACCESS

In general, women have entered biotech science occupations in proportion to their employment in science occupations for all industries, and in proportion to life science degrees earned by women. But minorities are underrepresented in most biotech occupations based on the same comparisons. There are several ways to enhance access to jobs. Much of the responsibility for improving access is in the hands of employers, who decide where to recruit and who to hire.

Employers have the final responsibility for the diversity of their workforces. Presently, the biotech workforce is extremely elite in its educational profile, and homogenous in terms of its racial and ethnic composition. In many ways, the biotech industry demonstrates enlightened employment practices. In addition to full health benefits, many firms offer daycare, employee ownership of stock, and support for continued education. Given these progressive policies, it is startling to learn that some of the major companies in Massachusetts, including some that are among the oldest (10 years +), do not yet have an affirmative action plan.

Biotech companies should develop and implement hiring plans to broaden and diversify their workforces. The gentlest way to do this would be to publicly recognize those companies that have established and successfully implemented hiring goals, with the hope that companies without plans would not want to be left out. A tougher approach would be to request to see affirmative action plans and implementation results from companies seeking special tax considerations, and other types of public benefits.

The administrators who recruit and admit students to training programs can also improve minority access to biotech professions. Junior colleges should be required to do a better job reaching out to local communities of color. So far, minorities are not well represented in training programs so far. Sometimes, people overlook the special efforts

necessary to recruit underserved populations. Recruitment strategies should address specific attendance barriers, such as transportation, course scheduling (daytime versus evening classes), and language (need for English tutoring). Some of these strategies may require financial support.

The state, and cities, should also review land use plans to identify whether there is land appropriately zoned for biotech manufacturing. Manufacturing is more likely to present opportunities for low skill labor, and if manufacturing locates near urban labor markets, the chances of people of color gaining access to these jobs improves. Conscious and well planned strategies, like that put into action by the City of Worcester, can have an effect on drawing biotech companies to certain locations, including urban areas. However, proximity to diverse, urban labor markets is not sufficient to ensure access. Education and progressive hiring strategies are equally important.

JOB QUALITY

We found that wages and benefits for non-degreed workers in Massachusetts biotech manufacturing tend to be lower than the annual average of production jobs for all manufacturing industries in the state. However, wages are likely to increase as firms become profitable. The greatest drawback in biotech production is that non-degreed workers are limited to jobs that are more or less dead-end in nature. Again, the onus for solving advancement shortcomings is on the firms themselves. Undoubtedly, they will come up with creative ways to enable their employees to develop new skills and advance in the company, if the alternative is having a high (and costly) turnover rate.

Worker safety is getting more attention as biotech matures. The major recommendation here is based on advice by occupational health and safety experts (Ducatman & Liberman, 1991). The current voluntary nature of safety procedures is cause for concern. Further research and ongoing monitoring of worker health should be conducted by professionals to fully determine the risks and effectiveness of current safety practices. If it can be shown that the industry is successfully and adequately monitoring itself, then additional protections should not be necessary.

If compliance becomes difficult, one option available to the state would be to adopt National Institutes of Health guidelines as basis for state law, which would enable the state to monitor facilities and worker health. Because most firms comply already with these guidelines (and often go further than the guidelines), their adoption should not prove to be an additional regulatory burden. However, since the guidelines do not have the force of law now, there is little room to enforce safety directly.

The good news is that Massachusetts is once again a world center for the research and commercialization of an important new technology. This fact bodes well for the state's ability to remain competitive in the world economy. The bad news is that biotech will not save the Massachusetts economy as we were led to believe. While it may contribute needed revenues and help to diversify the state's economy, *it will not put lots of people to work.* However, biotech can still make a positive contribution to the state's economy and to labor. Implementing the policies discussed here would help to maximize that positive contribution.

REFERENCES

SURVEYS, REPORTS & RESOURCES

Boston Redevelopment Authority.
Avault, John and Johnson, Mark. "Future Industries." (1990).
Dr. Howell, M. James. "The Howell Report. The Boston and Regional Economy into the 1990's: The Prospects for Economic Recovery." (1990)

Brainard, S., Podsedly, M., and Sutliff, L., "Biotechnology Industry Analysis." Chestnut Hill, MA. (1989).

Burrill, Steven G. and Lee, Kenneth B., of Ernst & Young, "Biotech 91: A Changing Environment." San Francisco, CA. (1990).

"Biotech 89: Commercialization." New York, NY. (1988).

"Biotech 88: Into the Marketplace." (1987).

"Biotech 86: At the Crossroad." (1986).

Dukakis, Michael (Governor). "Winning the Nineties: An Economic Strategy for Massachusetts." Boston, MA. (1990).

Economic Development Industrial Corporation.
"Who Benefits from Biomed? Real Jobs for Boston Residents." (1991).

Markusen, Ann R. "High Tech Jobs, Markets And Economic Development." Working Paper No. 403. Institute of Urban and Regional Development, University of Berkeley. (1983).

Martilla & Kiley. "Impact of Health Care & the Biomedical/Biotechnology Industries on the Massachusetts Economy." (1987).

Massachusetts Higher Education Task Force on Biotechnology, Report submitted to the Board of Regents of Higher Education. "Growth in the Nineties: Prospects for Strategic Economic Development in Boston." (1990).

National Center on Education and the Economy. "America's Choice: High Skills or Low Wages." Rochester, New York. (1990)

New England Board of Higher Education Commission on Academic Medical Centers and the Economy of New England. "Biomedical Research and Technology: A Prognosis for International Economic Leadership." (1988).

Occupational and Environmental Health Center. "Health and Safety Training in the Biotechnology Laboratory: A Practical Guidebook." Cambridge, MA. (1988).

Organisation for Economic Co-operation and Development. "Bio Technology: Economic and Wider Impacts." Paris, France. (1989).

Osborne, David. "State Technology Programs: A Preliminary Analysis of Lessons Learned." Washington, DC: the Council of State Policy & Planning Agencies. (1989).

Peter Feinstein, Peter Feinstein, Inc. "An Assessment of the Massachusetts Biotechnology Industry." (1990).

The High Tech Research Group. "Massachusetts High Tech: The Promise and the Reality." West Somerville, MA.: The High Tech Research Group. (1984).

U.S. Department of Commerce, International Trade Administration. "U.S. Industrial Outlook." Washington, DC. (1991)

National Technical Information Service. "New Developments in Biotechnology"; and "US Investment in Biotechnology." Springfield, VA. (1988).

Office of Technology Assessment. U.S. Congress. Washington, D.C. (see especially chapter 4: "US Investment in Biotechnology"; and chapter 8: "Training & Personnel Needs") (1988).

U.S. Department of Labor, Bureau of Labor Statistics. "Handbook of Labor Statistics." Bulletin 2340. Washington, DC. (1989).

Bay State Skills Corporation. Boston, MA. "The Massachusetts Biotechnology Directory: A Guide to Schools, Careers, and Biotechnology Companies." (1991).

INTERVIEWS

BASF Bioresearch: Joseph Michaels, Vice President of Administration & Pamela Barney, Human Resources Supervisor.

Bay State Skills Corporation: Fenna Hanes, Consultant.

Biogen:
Frank Burke, Vice President of Human Resources.
Parrish Gallaher, Manufacturing.

Boston School Department: Ann Hamadeh, Program Director of Science.

Cambridge Biotech: Nancy Keenan, Senior Human Resources Representative.

Consultant: Pat Patrick, consultant to biotech companies in establishing production facilities.

Consultant: Patricia Patrick, biotech consultant, Director New Business Development with ADIS International.

Enzytech: Mark Skaletsky, Chief Executive Officer.

Genetics Institute:
Zoltan Csimma, Vice President of Human Resources & Operations;
Barbara Covel, Director of Human Resources; and
John Cormier, Associate Director of Material Management.
Charles Williams, Manufacturing.

Genzyme:
Jack V. Heffernan, Vice President of Human Resources.
Richard Schoenfeld, Vice President of Manufacturing.

Hygeia Sciences:
Sally Seaver, Associate Director of Research & Development.
Lisa Gallaghan, Vice President of Human Resources.

ImmunoGen: James Embree, Director of Manufacturing.

Mass Biotech Council: Dr. Dana Ono, a founding Director.

Mass Board of Higher Education Regents: Barry Werner, Middlesex Community College, Coordinator of Biotech Survey (1989-90).

Matritech: Steve Chubb, Chief Executive Officer.

Repligen: Ramesh Ratan, Vice President of Finance & Administration.

Transgenic Sciences, Inc.: Andy Kurtz, Vice President of Human Resources & Jim Fleming, Purchasing Manager.

JOURNALS

Blakely, Edward & Nancy Nishikawa. "Reformulating the Incubator Model: Applications to Commercial Biotechnology" Berkeley: Biotech Industry Research Group. (1990).

"The Search for the Golden Goose: State Strategies for the Biotechnology Industry." Biotech Industry Research Group. Working Paper #500. (1989).

Blakely, Edward. "Developing The Biotech Industry: A Case Study of Regional Industrial Planning In the San Francisco Bay Area." Biotech Industry Research Group. Working Paper #476. (1988).

Blakely, Edward, Suzanne Scotchmer, and Jonathan Levine. "The Locational and Economic Patterns of California's Biotech Industry: A Preliminary Report." Working Paper #475. (1988).

Ducatman, Alan. M. & Liberman, Daniel. "Occupational Medicine: The Biotechnology Industry." Philadelphia: Hanley & Belfus, Inc., vol. 6, no. 2. (1991).

Glasmeier, Amy. "Factors Governing the Development of High Tech Industry Agglomerations: A Tale of Three Cities." Regional Studies. Austin, Texas: School of Architecture, University of Texas. vol. 22.4, pp. 287-301. (1987).

"High-Tech Industries and the Regional Division of Labor." Industrial Relations, vol. 25, no. 2. (1986).

Hall, Peter, Lisa Bornstein, Reed Grier, & Melvin Webber. "Biotechnology: The Next Industrial Frontier." Working Paper #474. (1988).

Harrison, Bennett. "The Tendency Toward Instability and Inequality Underlying the 'Revival' of New England." Papers of the Regional Science Association, vol. 50. (1982).

Hymer, S. "The Multinational Corporation and the Spatial Divsion of Labor." In Robert Chen, ed., The Multinational Corporation: A Radical Critique. Cambridge: Cambridge University Press. pp. 140-207. (1979).

Malecki, Edward J. "High Technology and Local Economic Development" in Journal of the American Planning Association. 50(3): 262-269. (1984).

"Corporate Organization of R and D and the Location of Technological Activities." Regional Studies. 219-234. (1980a).

"Dimensions of R&D Location in the United States." Research Policy. 2-22. (1980b).

Markusen, Ann. R. "High Tech Jobs, Markets and Economic Development Prospects." Working Paper No. 403. California, Berkeley: Institute of Urban and Regional Development. (1983).

Norton, R.D., and Rees, J., "The Product Cycle and the Spatial Decentralization of American Manufacturing," Regional Studies, vol. 13,1979, pp. 141-151.

Osterman, Paul. "New Technology and the Organization of Work" Work America. pp. 5-6. (1990).

Shearman & Burrell. "New Technology Based Firms & the Emergence of New Industries: Some Employment Implications" vol.3, no.2, New Technology, Work and Employment pp. 87-99. (1988).

Storper, Michael. "Oligopoly and the Product Cycly: Essentialism in Economic Geography." Economic Geography, vol. 61, no. 3. (1985).

Vernon, Raymond. "International Investment and International Trade in the Product Cycle." Quarterly Journal of Economics, 80. (1966).

BOOKS

Birch, David. The Job Generation Process. Cambridge: MIT Program on Neighborhood and Regional Change. (1979).

Job Creation in America. New York, NY.: The Free Press. (1987).

Blakely, Edward. J. Planning Local Economic Development. Newbury Park: Sage Publications, Inc., vol. 168. (1989).

Bruyn, Severyn T. & Meehan, James. Beyond the Market and the State. Philadelphia: Temple University Press. See chapter 9 for Schramm. (1987).

Cohen, Stephen. S. & John, Zysman. Manufacturing Matters. New York: Basic Books, Inc., Publishers. (1987).

Hall, P. & Markusen, A. Silicon Landscapes. Boston: Allen & Unwin. (1985).

Harrison, B. & Bluestone, B. The Great U-Turn. New York: Basic Books, Inc., Publishers. (1988).

The Deindustrialization of America. New York: Basic Books. (1982).

Kenney, Martin. Biotechnology: The University-Industry Complex. New Haven: Yale University Press. (1986).

Markusen, A., Hall, P. & Glasmeier, A. High Tech America. Boston: Allen & Unwin. (1986).

Osborne, David. Laboratories of Democracy. Boston: Harvard Business School Press. (1988).

Richardson, Harry. Regional Economics. Chicago, Il.: University of Illinois Press. (1978).

Summers, A. & Luce, T. Economic Development Within The Philadelphia Metropolitan Area. Philadelphia: University of Pennsylvania Press. (1987).