The Life Science Industry of New York City: Obstacles and Recommendations Towards Regional Development

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A Thesis in the Field of Biotechnology Management

For the Degree of Master of Liberal Arts in Extension Studies

Harvard University

May 2018

Abstract

The life science industry has localized into clusters, due to the localization of small and large life science companies, academic institutions that conduct biomedical and scientific research, sources of funding for early stage companies, and support from local, state and federal governments. While there are life science clusters all over the United States, Greater Boston and the Bay Area are considered the top two life science clusters in the country, and are considered life science hubs due to the large-scale localization of companies, research institutions, funding and government support.

While New York City has a life science cluster, they are not considered a life science hub because they lack the infrastructure and resources that Greater Boston and the Bay Area possess. Three hypotheses were created to investigate potential obstacles that are impeding the growth of New York City's life science industry. The first hypothesis states that the lack of affordable lab space was an obstacle impeding New York City's life science industry. The second hypothesis states that the lack of local venture capital funding impeded the growth of New York City's life science industry. The third hypothesis states that the lack of entrepreneurial culture within academic technology transfer offices impeded the growth of New York City's life science industry. A case study approach was used to examine the structure of New York City life science companies. The lack of lab space in New York City has resulted in the growth of virtual life science companies that outsource research and development. Furthermore, parent and subsidiary life science companies, or companies that procure intellectual property or pre-clinical therapeutic candidates and form separate companies to market their procurements, have developed in New York City to adapt to the lack of lab space. The

structure and operations of two parent and subsidiary model companies, Roivant Sciences and Fortress Biotech, were studied.

While the existence of local venture capital firms was not an issue in New York City, these firms did not invest in local life science companies, which hinders the growth of companies in New York City. The technology transfer offices of New York City university and medical institutions implemented measures to progress research to the pre-clinical stage and create start-up companies; however, the start-up companies that were formed from technology transfer offices did not remain in New York City. A case study of Roivant's business operations revealed a structure that prioritized financial return on investment over the commercialization of therapeutic products; in addition, parent and model subsidiary companies such as Roivant and Fortress Biotech also impeded the growth of the life science industry by reducing the availability of quality management and scientific talent in the city.

I made three recommendations, aimed at improving New York City's life science industry. First, I recommend the construction or renovation of affordable lab spaces to include mixed-use spaces that are suitable for medium sized companies with the incorporation of common spaces that encourage informal interaction amongst the life science community. Second I recommend cost of living subsidies, either from the state or municipal government, or from private sector funds, for founders or CEOs that want to locate their start-up companies in New York City. Third, I recommend grants to encourage the formation of local start-up companies that spin off from technology transfer offices, and public-private partnerships between the local government and local venture capital firms. Finally, New York City must advocate for traditional life science

companies that conduct in-house R&D to discourage the creation of virtual companies and parent and subsidiary companies.

Acknowledgements

I would like to extend my utmost gratitude to my thesis director, Dr. Don Kirsch, for providing guidance, sharing his expertise and stories about his career in the pharma industry, and for his patience. I am also truly thankful that Don took time to introduce me to many experts in the life science and biotechnology industry. His advice and connections have shaped my thesis in a remarkable manner.

I would also like to thank my thesis advisor, Dr. Steven Denkin, for encouraging me to submit my thesis earlier than I had originally planned, because he recognized the timely nature of my thesis topic.

I would like to extend gratitude to Barry Frankel, Dr. Eric Gordon, Dr. John Diekman, Dr. Hugh Reinhoff, Matt Gline and Dr. Richard Silverman, for sharing their perspectives through our interviews, and for giving me an opportunity to learn about their particular niches in the life science ecosystem.

Next, I would like to thank my former work supervisors, Dr. Gregg Tucci, Dr. Julie Murthy, and Dr. Sirinya Matchacheep, and my former work colleagues, for their constant support of my decision to pursue a Master's degree at the Harvard Extension School, and for encouraging lifelong learning. I would also like to thank my current work colleagues at Safety Partners for their support and for sharing their perspectives of the NYC life science industry.

Finally, I would like to thank my wonderful family. To Simon, thank you for your constant encouragement, and for taking more than your share of the child rearing and household duties so I could pursue a degree and create this thesis. To my kids, Sirah and

Casey, thank you for your patience while Mommy was “busy with school”. I love you all dearly.

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Chapter I

Introduction

This chapter describes the background of the life science industry and regional life science clusters. It also presents the research problem, and introduces my hypotheses and case study approach.

The Biotechnology and Life Science Industry

Biotechnology is broadly defined as any commercial biological product that is created through applied science and technology (Bud, 2009). Biotechnology Innovation Organization, or BIO, the largest biotechnology industry organization in the United States, subdivides biotechnology into five areas: agricultural feedstock and chemicals; drugs and pharmaceuticals; medical devices and equipment; research, testing and medical laboratories; and bioscience-related distribution (Andres, 2017). Within the biotechnology sector, the life science industry includes the drug and pharmaceutical, and medical devices and equipment sectors of the biotechnology industry, and the pharmaceutical industry (Anderson, 2004). The North American Industry Classification System (NAICS) defines life science employment within the following categories: pharmaceutical manufacturing; research and development (R&D) in biotechnology; R&D in life sciences; analytical laboratory instrument manufacturing; and medical testing laboratories (Steele, 2017; Appendix A).

Life Science Industry Contributions to the Economy

In the United States, the life science industry has been a steady source of employment and wages for decades. Employment increased by 9.7% from 2001-2014, with over 1.5 million employees in 2014. In addition, the average annual wage earned by an employee in the life science industry was over $94,000. (TEConomy/BIO, 2016). During the recession in 2008-2009, unemployment in the life sciences decreased by a smaller percentage than in other industries, and job recovery was more rapid in the life sciences than in other industries (TEConomy/BIO, 2016).

Industry Clusters and Hubs

Michael Porter created the concept of an industry cluster, which is a localized region of companies and institutions that are connected through a common industry (1988). Successful clusters achieve a fine balance between competition and collaboration amongst the companies, drive innovation forward, and facilitate the formation of new companies (Porter, 1988). Employees of a particular industry benefit from working in a cluster. Since there is competition amongst companies for employees, wages are raised to entice employees. In addition, transitioning from one company to another is easier due to the geographical proximity of companies and the formal and informal network connections that occur as a result of the geographical proximity. Employers benefit from the availability of managerial and technical talent that have been able to gain experience through employment at a variety of different companies.

An industry hub is a type of industry cluster; however, a hub has a higher concentration of interconnected companies and institutions than normal clusters. As a

result, a hub is a central cluster for a larger geographical area. For example, while there are technology clusters throughout the United States, Silicon Valley in the Bay Area is considered to be the major technology hub, due to the high concentration of companies within the area.

Components of a Successful Innovation Cluster

Certain industries, such as the technology and the life science industry, rely on innovation to drive companies forward. To create a region based on technological innovation, increases in innovation occur when the commercial sector of any particular industry works with the public sector to find and develop scientific and technological discoveries (Smilor, 1989). There are five main segments that must collaborate in order to form a successful innovation cluster: research universities and institutions; support groups or institutions; local, state and federal government; large, established companies and start-up companies (Smilor, 1989; Fieldsteel, 2013).

Research Universities and Institutions

Research universities and institutions are the source of innovations and the source of managerial and technical talent. Innovations are obtained by sourcing intellectual property, or IP, from universities and institutions. Traditionally, this process is facilitated by the university's technology transfer office (TTO), which works with the technological inventor to obtain patents and license the IP to suitable companies that can potentially commercialize the innovations into products or services (DeVol, 2017). Recently, innovations have transitioned from the public sector into the private sector in two other

ways: direct partnerships with private sector companies, and TTO-facilitated formation of start-up companies, which are usually founded by the inventor of the technology.

Research universities and institutions also provide scientific and managerial talent that receive training through academic coursework and research. Research universities are also starting to provide non-academic learning opportunities through their development of academic trade organizations. For example, the Harvard Biotech Club hosts a series of career-orientated seminars for medical and science graduate students that focus on topics such as business development and start-up formation.

Support Groups

Local support groups, or trade organizations, provide networking and advocacy support to companies within the cluster (Fieldsteel, 2003). For example, the Massachusetts Biotechnology Council, commonly known as MassBio, is a trade organization that provides networking support, lists of resources, informational seminars, industry data, and advocacy for life science organizations throughout Massachusetts. The California Life Sciences Association offers analogous support for life science companies in California. Support groups provide a formal forum for collaboration and connection. Smilor also categorizes venture capital (VC) firms as support groups (1989). While VC firms might not fit the standard definition of a support group because they invest in companies for the potential return on investment if the company succeeds, VC firms do provide managerial support and mentoring.

Local, State and Federal Government

The government offers support in the form of financial aid, infrastructure, and legislation that is intended to ease the obstacles that companies face when attempting to start or develop their businesses. Local governments provide support by building and maintaining infrastructure, and through legislative measures or other initiatives aimed at maintaining the workability and livability of the region. Examples of initiatives include the renovation or construction of a new high school to improve the resources and space for students, which encourage families to settle into the city or town (Smilor, 1989).

The state government primarly provides funding for various components of the industry. According to Fieldsteel, state governments should: provide funding for universities and colleges, which are the sources of IP and talent; create groups or organizations that focus on economic development of that particular industry; and create funds or tax incentives that encourage businesses to grow in the state (2013). For example, in California, companies can apply for the California Competes tax credit and the California R&D tax credit (California Life Sciences Association, n.d.)

The federal government provides funding and support in a number of ways. Small businesses can apply for a Small Business Innovation Research Grant (SBIR) or Small Business Technology Transfer Research Grant (STTR) through the U.S. Small Business Administration (n.d.). Certain industries are indirectly affected by federal funding. For example, in the life science industry, the IP licensed from research universities is largely funded by the National Institutes for Health (NIH), which awards grants to biomedical science researchers.

Large, Established Companies

Large, established companies play three main roles in a cluster: create employment for residents in the region; source IP from universities, institutions and smaller companies; and develop managerial and technical talent (Smilor, 1989). One example of a large, established biotechnology company is Genentech (now part of Roche) in San Francisco, California.

Start-up Companies

Start-up companies play a role in an industry cluster by obtaining IP from research institutions in order to commercialize discoveries into tangible products or services (Fieldsteel, 2013). While they do not have the vast financial resources that large companies have, start-up companies have the freedom to pursue projects that large companies might ignore.

Life Science Industry Clusters and Hubs

In the United States, there are many life science clusters in all areas of the country. To determine the size and impact of each life science cluster, Jones Lang LaSalle (JLL), a real estate professional services firm, ranks the clusters annually based on the following criteria: the percentage of employees that are employed by the life sciences industry in that particular region; employment growth; venture capital funding; NIH funding; lab rental prices; and lab occupancy rates (2017). From 2015 to 2017, Greater Boston was ranked the number one life science cluster in the United States. The

San Francisco Bay Area was ranked second in 2016 and 2017. Since Greater Boston and the San Francisco Bay Area have consistently been ranked first and second, they are considered to be the life science hubs of the United States. Other clusters, such as Seattle, Raleigh-Durham in North Carolina, and New York City, tend to rank in the top 15, with fluctuations in rank from year to year (Jones Lang LaSalle, 2015; 2016; 2017).

San Francisco Bay Area

The San Francisco Bay Area, also known as the Bay Area, is defined by the Metropolitan Statistical Area (MSA) as San Francisco-Oakland-Hayward, in California (United States Census Bureau, 2015). While the Bay Area encompasses a large area, the urban center is located in San Francisco. The region is generally regarded as the birthplace of biotechnology, based on the formation of Genentech, the first biotechnology company, in 1976 (Hughes, 2011). Many prestigious research universities reside in the Bay Area, including the University of California (UC) San Francisco, UC Berkeley, and Stanford. According to the California Life Sciences Association 2018 Industry Report, over 76,000 people were employed by the life science industry in the Bay Area in 2017. In addition, $1.47 billion in NIH funding was granted to institutions in the Bay Area, and over $5 billion of life science VC funding was invested in the region (Radcliffe, 2017). There are large, established companies such as Genentech, Gilead, BioMarin and Bayer. There are also strong partnerships between the private and public sectors, as demonstrated through the California Institute of Quantitative Biosciences (QB3), which started in 2000 as a state government initiative to commercialize innovations in collaboration with their research universities (QB3, n.d.).

Greater Boston

Greater Boston is the colloquial term for the city of Boston and the surrounding suburban areas. The Metropolitan Statistical Area, or geographical region containing an area of high population density, the Greater Boston is defined as Boston-Cambridge-Newton, in Massachusetts (United States Census Bureau, 2015). While Boston is the urban center of Greater Boston, Cambridge is considered the life science epicenter of the region. Greater Boston is most known for Harvard University and Massachusetts Institute of Technology (MIT). They are also known for world class medical centers, such as the Massachusetts General Hospital, Brigham and Women's Hospital, the Boston Children's Hospital, Beth Israel Deaconess Medical Center and Dana-Farber Cancer Institute, which collectively received $1.12 billion in NIH funding in 2016 (Steele, 2017).

Greater Boston's status as a life science hub is supported by a ten-year, $1 billion state initiative that Governor Deval Patrick signed in 2008, which funded infrastructure improvements, new lab space, tax incentives and life science grants (The Office of the Governor, 2008). As a result, employment in the Massachusetts biopharma industry grew by 28% between 2006 and 2016, to over 66,000 employees, most of which are employed in the Greater Boston area. In addition, the region received over $2.14 billion in life science VC funding in 2016, and 59% of the companies were located in Cambridge (Steele, 2017). There are over 300 life science companies in the region, including the headquarters of large companies such as Pfizer, Sanofi, Novartis and Biogen.

In June 2017, Governor Charlie Baker proposed a five-year, $500 million life science initiative that would include $150 million in tax incentives and $295 in capital

spending, which demonstrates that the state is dedicated to the continued development of Greater Boston's life science hub.

Seattle

Seattle is an urban center on the northwest coast of the United States; the MSA defines the region as Seattle-Tacoma-Bellevue (United States Census Bureau, 2015). The region is known for the University of Washington and the Fred Hutchison Cancer Research Center. There are approximately 22,000 life science employees within 160 life science companies throughout the Seattle area (Economic Development Council of Seattle, n.d.). While the region has been ranked amongst the top ten life science clusters in the United States by JLL between 2015 and 2017 (Jones Lang LaSalle, 2015; 2016; 2017), the Governor's life science and global health development advisory council noted that Seattle's life science industry job growth was decreasing, mainly because state R&D tax incentives and funding were eliminated (TEConomy Partners, 2017).

Research Triangle Park (RTP), North Carolina

Research Triangle Park (RTP) is geographically defined by the three research universities that surround the area: Duke University, University of North Carolina at Chapel Hill, and North Carolina State University (Link, 2003). RTP is located within two MSAs: Raleigh; and Durham-Chapel Hill, in North Carolina (United States Census Bureau, 2015). The RTP is also a science park that was built in 1959 to encourage the growth of new businesses and the re-location of other businesses into the area (Link, 2003). Currently, RTP is home to small life science companies and larger companies

such as GlaxoSmithKline. According to the North Carolina Biotechnology Center, their life science industry employs over 66,000 people, and has the largest biological manufacturing and the third largest pharmaceutical manufacturing industries in the United States, according to the Economic Development Partnership of North Carolina (2016). As a result, JLL has ranked RTP within the top five life science clusters between 2015 and 2017 (Jones, Lang LaSalle, 2015; 2016; 2017).

New York City

New York City is the largest city in the United States, and consists of five boroughs: Manhattan, Brooklyn, Queens, the Bronx and Staten Island, according to the New York City Department of City Planning (n.d.). While the city is part of the New York-Newark, NJ-Bridgeport, CT MSA, New York City is often considered its own entity due to its large population density. There are many research universities, medical schools, and medical centers within the city, including Columbia University, New York University (NYU) Medical School, and Memorial Sloan-Kettering Cancer Center (Appendix B). In addition, New York City ranks second in the United States for NIH funding, with $1.4 billion of funding in 2017 (New York City Economic Development Corporation, 2018). Although New York City excels in biomedical research, the city is not as successful in biomedical commercialization. In 2015, for every dollar of NIH funding, New York City received $0.06 in VC investment (Partnership Fund for New York City, 2016).

Concerns about New York City's fledging life science industry have been present for decades. In 1999, the Center for an Urban Future, a New York City policy

organization, outlined how the city missed opportunities to develop their regional biotechnology industry due to the lack of life sciences infrastructure. In addition, New York City medical centers were not receptive to entrepreneurial efforts (Bowles, 1999). At the time, there were only 27 biotech companies in New York City. In the early 2000s, the city and state provided funding. For example, the Emerging Industries Fund invested $250,000 to $1.5 million to biotechnology and technology companies based in New York City (Archives of the Mayor's Press Office, 2001). In 2007, in a joint effort between the SUNY Downstate Medical Center and the New York City Economic Development Corporation, the BioBAT biotechnology facility was built. However, the facility was not able to attract tenants into the space (Kusisto, 2014).

In 2012, public policy analysts remarked that New York's bioscience industry: lacked vision; lacked dedicated funding for the life sciences; and needed accessible lab space for start-up companies (Zokowski, 2012). The New York City government responded through the creation of a $100 million program, in collaboration with Celgene, Eli Lilly and GE Ventures, to fund biotech start-up companies (Kusisto, 2013). The Alexandria Center for Life Science, a building in Manhattan for life science companies, was built to attract large pharmaceutical companies who wanted to place their corporate headquarters in New York City (Morris, 2014). However, the Partnership Fund for New York City, an organization that invests in city ventures, identified four key factors that are impeding the development of New York City's life science industry: lack of space; lack of entrepreneurial talent; lack of early stage capital; and lack of advocacy (Partnership Fund for New York City, 2016).

In December 2016, New York State and New York City announced initiatives to transform New York City into a life science hub. Governor Cuomo proposed a $650 million, ten-year initiative, which included: $250 million in tax incentives for new and existing life science companies; $200 million in grants for lab space, and allocation of 4.2 million square feet of space, available tax-free, for colleges and universities; $100 million in investment capital for start-up life science companies, with matching $100 million investments through the private sector; and $17 million investment to locate the JLabs Innovation Center into the New York Genome Center (Cuomo, 2017).

Mayor Bill de Blasio unveiled LifeSciNYC, a $500 million, ten-year initiative, which included: $100 million to build an Applied Life Sciences Campus; $50 million to expand R&D facilities in New York City medical centers and research universities; $10 million to invest in up to five new life science incubators; $20 million per year in matching funds for start-up companies; $7.5 million for internships in companies and research institutions; $300 million in tax incentives to encourage the building of commercial lab space; $7.5 million to draw in experienced entrepreneurs; $3.8 million for entrepreneurial training programs; the creation of a Life Sciences Advisory Council (NYC Office of the Mayor, 2016).

Since Governor Cuomo and Mayor de Blasio's announcements, many building developments have been announced or have been constructed. Alexandria opened the LaunchLabs, a biotechnology incubator within the Alexandria Life Sciences Center (Alexandria LaunchLabs, 2017). A $20 million investment into the Hudson Research Center on the west side of Manhattan proposes to convert the building into space for start-ups and medium sized life science companies (Fidler, 2017a). Construction of the

New York Life Sciences and Technology Center on the east side of Manhattan is scheduled to begin in 2018 (Fidler, 2017b).

Research Problem

The New York State and New York City life science initiatives have given the city a tremendous opportunity to transform their regional life science industry from a mid-sized cluster to a successful hub. However, in order to build a robust life science hub, New York City must allocate resources towards the obstacles impeding the development of the industry, and create solutions that address the obstacles. Four main obstacles that have been previously identified: a lack of affordable lab space, a lack of entrepreneurial talent, a lack of start-up capital and a lack of regional industry promotion.

This thesis investigates the main obstacles that are impeding New York City's life science industry through two approaches. In the first approach, three hypotheses were created, and data were obtained to test the validity of the hypotheses. It is possible that one or all of the hypotheses are valid, and that they are even interrelated. Based on the validity of these hypotheses, recommendations will be made to address the obstacles.

Despite obstacles to New York City's life science industry, companies are still able to form and develop in the city. How are they able to survive, despite the impediments to the life science industry in New York City? An investigation into this question led to the second approach, which was a case study of the strategies life science companies in New York City have used to survive in the regional industry.

Hypotheses

The three hypotheses that were investigated are:

1. The lack of affordable lab space is a significant obstacle impeding New York City's development as a life science hub.
2. The lack of early-stage capital is a significant obstacle impeding New York City's development as a life science hub.
3. The lack of entrepreneurial culture within the Technology Transfer Offices of New York City's academic and medical institutions is a significant obstacle impeding the city's potential as a life science hub.

Case Study

In the case study, the approaches that Roivant Sciences and Fortress Biotech are using to operate in the New York City life science industry were investigated, the consequences to their approaches were analyzed, and the implications of their approaches to the life sciences industry were considered. An investigation of Millennium Pharmaceuticals, a biotechnology company that was based in Greater Boston, was used to compare whether companies in different biotech clusters employed different approaches.

Objective

Through the three hypotheses and the case study approach, the overall objective of this thesis is to create a set of recommendations to improve New York City's life sciences industry. The recommendations could be the basis for a model of growth of the city's life sciences industry.

Chapter II

Methods

This chapter describes the methods of collecting information and data for the purposes of investigating the main obstacles that are hindering New York City's life science industry.

Identifying the Main Obstacles in New York City

To gain a broader understanding of the issues that New York City encounters when developing their life science industry, information from panel discussions at Xconomy's EXOME conference in May 2017 was gathered; the conference focused on the potential growth of New York City's Biotech sector. Interviews with Barry Frankel, the founder and former Managing Director of the Frankel Group LLC, a life science consulting firm that was based out of New York City and Cambridge, Massachusetts, also highlighted New York City's obstacles. Based on recommendations from New York City-based economic reports, suggestions from the speakers at the EXOME conference, and advice from Barry Frankel, three main obstacles that impeded New York City's life science industry were identified: the lack of affordable lab space; the lack of early-stage funding; and the lack of an entrepreneurial culture in universities and research institutions.

In order to determine which obstacles were relevant, and to identify potential causes, three hypotheses were created; the results of the hypotheses directed further analysis and potential recommendations. Within each hypothesis, metrics from five life science clusters were compared: the Bay Area; Greater Boston; Seattle; RTP and New

York City. The Bay Area and Greater Boston were selected because they were consistently ranked as the top two life science hubs in the United States, according to annual Life Sciences Outlook Reports by JLL (2017). Seattle and the RTP were also chosen as comparison regions because they are medium-sized life science regions with features that are similar to New York City.

Determining Lab Space Affordability

To determine whether the lack of affordable lab space is a significant obstacle impeding New York City's development as a life science hub. Three metrics were investigated: the price per square foot of leased lab space within each life science cluster; the vacancy rate of each cluster; and the number and price of life science and biotechnology incubators. The price per square foot of leased lab space and vacancy rates were obtained from reports by commercial real estate firms JLL and Alexandria Real Estate Equities. Alexandria is considered one of the top life science real estate firms in the United States, and has life science properties in New York City, San Francisco, Greater Boston, and Seattle. If affordable lab space is the most significant obstacle in New York City, then the region would have the highest leased lab space price, the lowest vacancy rate, and either a lack of incubators or incubators with the highest tenancy price. To address the lack of affordable lab space, recommendations would address the optimal types of lab spaces, such as incubators or rental spaces for companies outgrowing the start-up stage, the optimal location to locate lab spaces, and the types of partnerships that could be involved in the development of affordable lab space.

Measuring Early Stage Capital Investment for Life Science Companies

Determining whether the lack of early-stage capital is a significant obstacle impeding New York City's development as a life science hub. While grants and awards from the government and private entities are sources of funding for start-up and smaller companies, financial support from VC firms is one of the main sources of large scale funding.

VC firms tend to invest locally, or in nearby industry clusters (Rowley, 2017). If the lack of early-stage capital funding is an issue for New York City, then one of two issues exist; either New York City lacks VC firms that invest in biotechnology and life science companies, or New York City VC firms are not investing in local life science companies. EndPoints News listed the locations of the top one hundred venture capital firms that invested in life science companies in 2016 (Carroll, 2017). Out of the top one hundred firms, the number of VC firms that were located in each of the five life science clusters were determined. If New York City lacked VC firms that invested in life science, the number of firms that exist in New York City would be appreciably lower than the number of firms in the Bay Area or Greater Boston.

The data from EndPoints News was analyzed to identify the top VC firm in each life science cluster, based on the total equity invested in United States biotechnology and life science companies.

Once the top VC firm was identified, the websites of the companies that were in each VC firm's biopharma, therapeutics or life science portfolio were analyzed to determine the location of each company. If a company listed multiple locations, the company headquarters or the first location listed on the company's website was selected

as its primary location. The top VC firm in North Carolina was not analyzed because it did not have a functioning website, and information regarding the firm was unavailable. If New York City VC firms invested in local companies, the location of the life science companies in the firm's portfolio would be located in New York City. However, if New York City VC firms did not invest locally, a majority of the companies in their portfolio would be located elsewhere. Recommendations aimed towards the promotion of early-stage capital in New York City would involve initiatives that could entice local investment by New York City VC firms, public-private partnerships to provide funding to start-up companies.

Measuring Entrepreneurial Culture within Academic Institutions

Technology transfer offices in New York City were studied to determine whether an underdeveloped entrepreneurial culture within New York City's academic and medical institutions is a significant obstacle impeding the city's potential as a life science hub.

New York City has many institutions that engage in biomedical research; the scientific research, the technical talent of scientists and engineers, and the managerial talent from these institutions can all contribute to the development of the commercial life science sector if there are adequate measures in place to transition innovations and talent from academia to industry.

In research institutions, TTOs oversee the licensing of IP from their institutions to companies in the commercial sector (DeVol, 2017). TTOs also facilitate partnerships between researchers and companies, and provide resources to entrepreneurs who want to use the institution's innovations to create start-up companies. Since TTOs are bridges

between academic researchers and the commercial sector, they are responsible for the flow of scientific discoveries into the commercial sector, and play a central role in the life science industry (Booth, 2016). As a result, a successful life science hub should have successful TTOs in their research institutions, and start-up companies that come out of institutions with the assistance of TTOs should locate their companies near the source of the scientific innovations. If New York City lacks an entrepreneurial environment within their academic and research institutions, then their TTOs might not be successful when compared to TTOs in other life science clusters. However, a TTO could be successful with respect to licensing technology, but might lack resources and capabilities to support their spin off start-up companies; as a result, the companies move out of the region.

Data from the Milken Institute's 2017 University Technology Transfer and Commercialization Index was used to determine the success of various academic institutions in the five life science clusters. The rankings in the index were based on four variables that were collected from 2012 to 2015: patents issued, licenses issued, licensing income and start-up companies formed (DeVol, 2017). While the index did not sub-divide their data by the commercial sectors, the index gave an overall perspective of the performance of the TTOs in the academic institutions. The most successful university TTO in each life science cluster was identified, and the locations of the start-up companies that were spin-offs of each university were determined. While the names of the spin-off companies were found on the TTO websites, they were also found in the portfolios of accelerators and entrepreneurial organizations that were affiliated with the universities. For example, the names of many of the life science companies that were

spin-offs from MIT were found on the Deshpande Center for Innovation's website, because the center is part of the MIT entrepreneurial ecosystem.

If New York City lacked successful TTOs, the index rankings for the city's universities would be lower when compared to TTOs in other life science clusters. If New York City universities lacked the resources and capabilities to support their spin-off companies, a significant portion of their companies would not be located in New York City. Recommendations aimed at improving the entrepreneurial culture of research institutions would involve TTO-related programs and initiatives to keep spin off start-up companies in the city and other programs to improve the entrepreneurial culture in research institutions.

Interviews with Venture Capital Experts

To gain an understanding of the life science ecosystems of a particular region, three VC experts were interviewed: Dr. Eric Gordon; Dr. John Diekman, and Dr. Hugh Rienhoff. While the VC experts are based in the Bay Area, they are also familiar with Greater Boston's and New York City's life science industries. In addition, they have experience as senior managers and executives in biotechnology companies.

Dr. Eric Gordon is a Partner at Skyline Ventures in Palo Alto, California. He received his Ph.D. in medicinal chemistry from University of Wisconsin in Madison, and was a post-doctoral researcher at Yale University. He was the head of medicinal chemistry at Squibb and Bristol Myers Squibb, and the Vice President of Research and Director of Chemistry at Affymax, which was later sold to Glaxo in 1995. In 1996, he became the co-founder, President and Chief Scientific Officer of Versicor, which was

acquired by Pfizer. He was also the Senior Vice President of Sunesis Pharmaceuticals until 2002. He joined Skyline Ventures in 2002 (Skyline Ventures, 2012).

Dr. John Diekman is a Founding Partner at 5AM Ventures in San Francisco. He received his Ph.D. in Chemistry from Stanford University. He was Chairman and CEO of Affymetrix, Chairman and Managing CEO of Affymax, and Founder and Managing Director of Bay City Capital. He became Managing Partner of 5AM Ventures in 2002 and became Founding Partner in 2016. He is on the Board of Directors of IDEAYA, Igenica and Wildcat, and was on the Board of Directors of Ambrx, Calibrium, Cellular Research, Chemdex, Envoy, Ingenuity, LFL BioSystems, Marcadia and PhaseRx (5AM Venture Management LLC, 2018).

Dr. Hugh Rienhoff is a former Partner at New Enterprise Associates in San Francisco. He received his M.D. in Internal Medicine at Johns Hopkins University School of Medicine. He was the Founding Director of Healtheon WebMD, Director of Sunesis, Chief Executive Officer of DNA Sciences and FerroKin BioSciences. He currently has dual roles as the CEO of Imago BioSciences and Director of MyDaughtersDNA.org (LinkedIn, n.d.)

Each expert was given the same set of questions to answer. The questions were:

1. San Francisco and Boston are two successful biotechnology hubs. What common factors are responsible for their successes, and what factors are unique to each city?
2. There are differences between New York City's biotechnology hub and the successful biotechnology hubs in San Francisco and Boston. Do you agree? If so, what are the main differences?

3. What would you do to improve the biotechnology industry in New York City?
4. An established biotechnology or pharmaceutical company is usually the source of managerial talent in a region. Do you think a biotechnology hub can develop or survive without that source?
5. There is currently $1.1 billion directed towards building New York City as a life sciences hub. A majority of the funding is earmarked for affordable lab space and direct funding for start-up companies. Do you think this is a productive use of the fund?
6. There is more biotechnology incubator space in San Francisco and Boston than in New York City. Do you think this difference is important?

Chapter III

Results

This chapter outlines the information and data collected, based on the approaches described in the Methods section.

Overview

The lack of lab space and early stage capital, and issues with the entrepreneurial culture of the research institutions were major themes at the *NYC Biotech Seizes the Momentum* conference in New York City. Creating lab space to meet the demands of current and potential companies is a concern for Jenna Foger, Senior Vice President of Science and Technology at Alexandria Real Estate Equities. "New York City has a larger research base than Cambridge, will we need to scale our wet lab space accordingly in the future to meet our needs? We also need to consider localization of space." (Foger, 2017). For companies in New York City that are growing out of the start-up phase, the scarcity of larger lab spaces is a major concern. Dr. Piraye Beim, CEO of Celmatix, Dr. Eric Schadt, CEO of Sema4, and Dr. Gordana Vunjak-Novakovic, Founder of Epibone, Tara Biosystems and East River Biosolutions collectively asked about a biotech company's ability to "grow up" in New York City, which has one of the highest real estate markets in the world. Dr. Beim also mentioned that procuring venture capital funding was a challenge, and that the culture of angel investing did not exist in New York City until recently. (Beim, 2017).

The entrepreneurial environment of research universities was also a theme at the conference. Dr. Harold Varmus, Professor of Medicine at Weill Cornell Medicine and co-

chair of the LifeSciNYC Advisory Council asked, "What about the academics who do not have access to good technology transfer departments? Maybe New York City's initiatives should address that issue" (Varmus, 2017). Dr. Mike Foley, Director of the Tri-Institutional Therapeutics Discovery Institute (Tri-I TDI), also noted that accelerating "quality biomedical research projects from institutions to the commercial sector through the 'build to buy' approach will attract people into New York City's ecosystem" (Foley, 2017). The entrepreneurial culture of universities in New York City was also a concern for Barry Frankel, Chief Business Officer of Sedor Pharmaceuticals and Founder of the Frankel Group LLC. He observed that research institutions in New York City are not "setting up an environment for risk taking and discovery, and should encourage academic research that does not end at theoretical discovery, but moves to early drug development through the implementation of physical incubators at the university." (B. Frankel, personal communication, October 4, 2017).

Availability of Affordable Lab Space

This section outlines the rental rates and vacancy rates of leased laboratory rates in Greater Boston, the Bay Area, Seattle, RTP, and New York City. The section also outlines the number and price of life science incubators in the five life science regions.

Leased Laboratory Space and Vacancy Rates

Based on commercial lab space rental prices from JLL (2017), Alexandria (2016), and CBRE New England (2017), lab rental costs in Cambridge, the central location of biotechnology in Greater Boston, are $74.77 per square foot and $64.90 in Mission Bay, San Francisco (Table 1).

Table 1: Cost of Leased Wet Lab Space in Greater Boston and the Bay Area, Per Square Foot, in 2016

City	Source	Cost/sq. ft.	% Vacancy
Greater Boston			
Cambridge	JLL	$75.05	3.55
	Transwestern	$75.48	3.3
	CBRE New England	$74.55	2.6
	Alexandria	$74.00	1.3
	AVERAGE	*$74.77*	*2.7*
Seaport District	JLL	$70.12	4.2
Suburbs (128 Corridor)	JLL	$42.65	12.6
	CBRE New England	$45.23	8.6
	AVERAGE	*$43.94*	*10.6*
City	**Source**	**Cost/sq. ft.**	**% Vacancy**
San Francisco Bay Area			
Mission Bay	JLL	$65.00	5
	Alexandria	$64.80	2.2
	AVERAGE	*$64.90*	*3.6*
South San Francisco	JLL	$51.72	3
	Alexandria	$51.00	not available
	AVERAGE	$51.36	3
Palo Alto/Stanford Research Park	Alexandria	$52.00	not available

As expected, lab rental prices for smaller life sciences clusters are lower; with an average rental cost of $46.69 per square foot in Seattle and $14.94 per square foot in RTP, North Carolina (Table 2).

Table 2: Cost of Leased Wet Lab Space in Seattle and RTP, Per Square Foot, in 2016

City	Source	Cost/sq. ft.	% Vacancy
Seattle			
Lake Union	JLL	$39.37	1.3
	Alexandria	$54.00	not available
	AVERAGE	$46.69	1.3
North Carolina			
Research Triangle Park	JLL	$14.94	24

In the borough of Manhattan in New York City, the cost of lab rental space is $83 per square foot, which is higher than rental costs in Greater Boston and the Bay Area (see Table 3). In addition, the scarcity of available data for New York City and the vacancy rate indicates the lack of lab space that is currently available. When the Alexandria Center for Life Science opened in 2011 (Mullin, 2014), it was one of the few commercial, non-incubator facilities in Manhattan with leasable lab space. Even though commercial lab buildings such as the Hudson Research Center are starting to open, the lab vacancy rate in New York City will be close to zero until the demand for space is met.

Table 3: Cost of Leased Wet Lab Space in New York City, Per Square Foot, in 2016

City	Source	Cost/sq. ft.	% Vacancy
New York City			
Manhattan	JLL	not available	0
	Alexandria	$83.00	not available
Brooklyn	JLL	$31.77	2
Long Island	JLL	$23.50	13.2
Westchester County	JLL	$49.00	7

Biotechnology Incubators

Biotechnology incubators are a significant part of the Bay Area's and Greater Boston's life science hubs, with fourteen and twelve incubators, respectively (see Table 4). In the Bay Area, almost half of the incubators are run by QB3. In Greater Boston, LabCentral is the largest and most well-known incubator in the region, and recently expanded with the opening of LabCentral 610, a 33,000 square foot facility for start-ups and medium-sized life science companies (LabCentral, n.d.(b)). Conversely, incubators are not as prevalent in Seattle or the RTP (Table 5).

Table 4: List of Biotechnology Incubators in Greater Boston and the Bay Area

GREATER BOSTON	
Name of Incubator	City
ABI-Lab	Natck
Arsenal Lab Space	Watertown
AstraZeneca Gatehouse Park BioHub	Waltham
BioSquare	Boston
Creagen (C2I)	Woburn
JLabs @ LabCentral	Cambridge
LabCentral	Cambridge
Mansfield Bio-incubator	Mansfield
Mass Innovation Labs	Cambridge
Pagliuca Harvard Life Lab	Cambridge
The Engine	Cambridge
Tufts LaunchPad	Boston

SAN FRANCISCO-BAY AREA	
Name of Incubator	City
Bayer CoLaborator	San Francisco
Berkeley BioLabs	Berkeley
Bioscience Laboratories	San Francisco
Catalyst@Berkeley	Berkeley
JLabs @ QB3	San Francisco
JLabs @ SSF	San Francisco
Molecular Medicine Research Institute-Translational Research Center	Sunnyvale
QB3 Garage @ Berkeley	Berkeley
QB3 Garage @ UCSF	San Francisco
QB3-EBIC (East Bay Innovation Center)	Berkeley
QB3@953	San Francisco
San Jose BioCube	San Jose
StartX@QB3	Palo Alto
Triple Ring Labs	Newark

Table 5: List of Biotechnology Incubators in Seattle and the RTP

SEATTLE	
Name of Incubator	City
Accelerator Life Science Partners	Seattle
CoMotion Labs - University of Washington	Seattle
Icogenex Bioincubator Lab	Seattle

NORTH CAROLINA/RTP	
Name of Incubator	City
BD Technologies and Innovation	RTP
BioLabs North Carolina	Durham
First Flight Venture Center	RTP
Technology Incubator @ Centennial Campus	Raleigh

New York City has six biotechnology incubators, with a seventh incubator scheduled to open in June 2018 (Table 6). In New York City, the incubators were founded by various individuals and organizations. For example, the Harlem Biospace was co-founded by a faculty member of Columbia University's Biomedical Engineering department, with funding from the New York City Economic Development Corporation, or NYCEDC (Sia, 2015). BioLabs@NYULangone was founded by the BioLabs organization, and was the first recipient of a $5 million grant from the LifeSciNYC initiative (NYC Office of the Mayor, 2017).

Table 6: List of Biotechnology Incubators in New York City

NEW YORK CITY	
Name of Incubator	City
Alexandria LaunchLabs	Manhattan
Audubon Business and Technology Center	Manhattan
BioBAT at Brooklyn Army Terminal	Brooklyn
BioLabs@NYULangone	Manhattan
Downstate's Biotechnology Incubator	Brooklyn
Harlem Biobase	Manhattan

JLabs @ NYC (Open in June 2018)	Manhattan

The monthly price to rent a bench at the incubators varies by region. BioLabs have locations in Boston, New York and North Carolina, and while they all have membership fees of $400 per month, a lab bench costs $3000 per month in Boston (Tufts LaunchPad, n.d.) and $3600 in New York (BioLabs New York, n.d.). In the Bay Area, a lab bench at StartX@QB3 and at Bioscience Laboratories costs $1500 per month (Lee, 2014; C. John, personal communication, January 26, 2018). The bench rental rate in Boston's BioLabs reflects the market rate in the Greater Boston region; the rental rate in LabCentral ranges from $4090 to $4645 (LabCentral, n.d(a)), and the rate at ABI-Lab is $3500 per month (ABI-Lab, n.d.). Conversely, the cost to rent a bench at an incubator in a smaller life science cluster is lower. A bench rental at CoMotion Labs in Seattle costs $825 to 900 per month (K. Franz, personal communication, January 26, 2018). In New York City, the rental rate per bench varies by the incubator. Space at Harlem Biospace costs $995 per month (Sia, 2015), while at Alexandria LaunchLabs, the monthly rate is $1995 (Alexandria LaunchLabs, 2017).

Availability of Early Stage Capital for Life Science Companies

Every year, EndPoints News identifies VC firms that invest in U.S. biotechnology companies, calculates the total equity each firm invested per year, and ranks firms based on the calculations (Carroll, 2017). Based on their VC firm ranking, the number of top 100 VC firms in each life science region was determined (Figure 1). While the Bay Area has the most VC firms represented in the top 100, Greater Boston only has six more VC firms in the top 100 when compared to New York City. Based on the total equity invested

in 2016, New York City has more VC firms that invest in U.S. biotech than expected. Out of the top ten VC firms that invest in U.S. biotechnology, four are located in Greater Boston, three are located in the Bay Area and two are located in New York City (Appendix C).

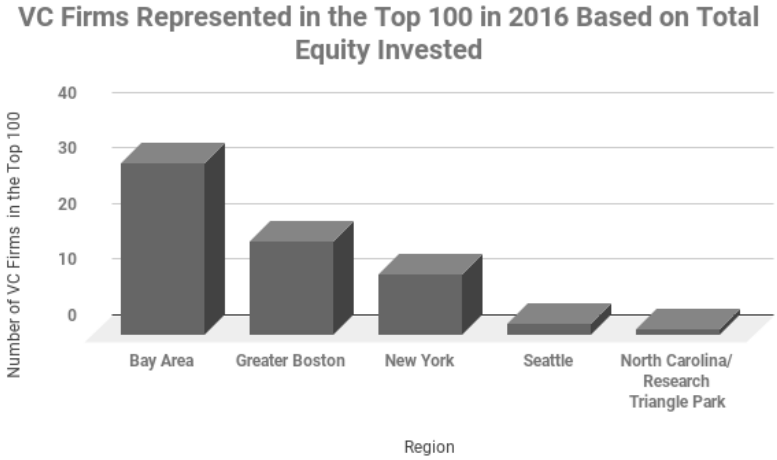

Figure 1: Number of VC Firms the Invested in U.S. Biotech Represented in the Top 100 in 2016. Data was obtained from EndPoints News (Carroll, 2017).

Locations of Life Sciences Companies in VC Portfolios

Data from EndPoints News indicated that there are many VC firms in New York City that are investing in life science. However, the data did not indicate where New York City VC firms are investing; to gain a better perspective, the top VC firm in each region was selected, and the current location of the companies in their biopharma or life science portfolio were identified.

In Flagship Pioneering, the top VC firm overall and in Greater Boston, 82% of the companies their therapeutics portfolio are based in Greater Boston (Figure 2 and Appendix D). The biopharma portfolio of New Enterprise Associates, the top VC firm in

the Bay Area, exhibits a different distribution of companies (Figure 3 and Appendix E). Even though the Bay Area is a successful life science hub, over 23% of the companies in their portfolio are located in Greater Boston, and only 14% are located in the Bay Area.

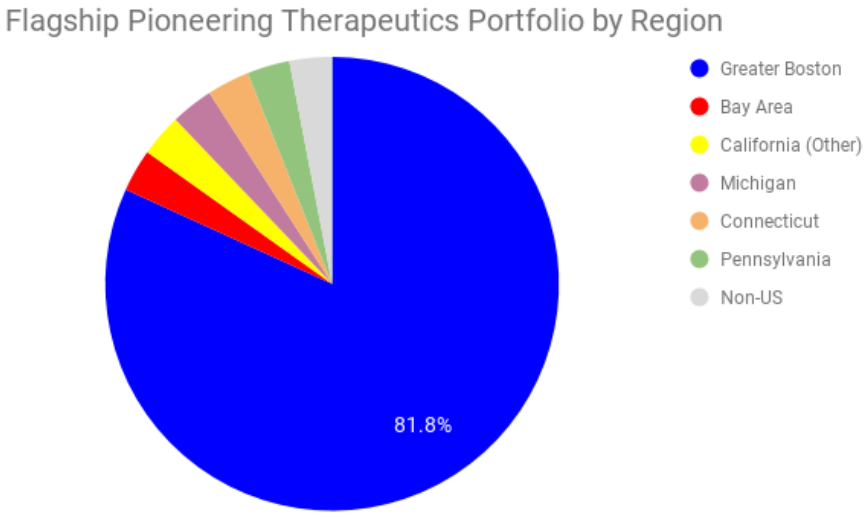

Figure 2: Percentage of companies in Flagship Pioneering's therapeutics portfolio by region, as of November 2017. Aside from Greater Boston (blue), each region represents 3.3% of the portfolio.

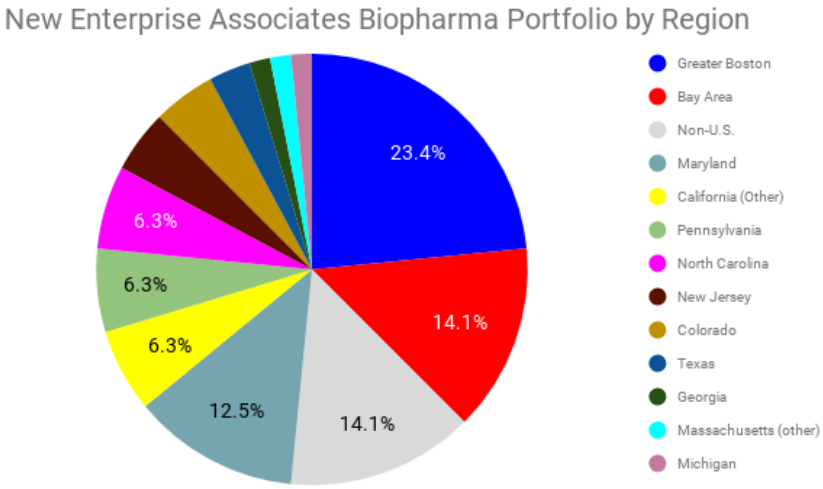

Figure 3: Percentage of companies in New Enterprise Associates' biopharma portfolio by region, as of November 2017. Greater Boston (blue) represents 23.4% of companies and the Bay Area represents 14.1% of companies.

The VC firm in Seattle, Frazier Healthcare Partners, also invests in companies that are in larger, more established life science clusters. In the life science portfolio of Frazier Healthcare Partners, the top VC firm in Seattle, 33% of the companies are based in the Bay Area, and 14.5% of the companies are located in San Diego (Figure 4). However, 11% of Frazier's companies are based in Seattle (Appendix F).

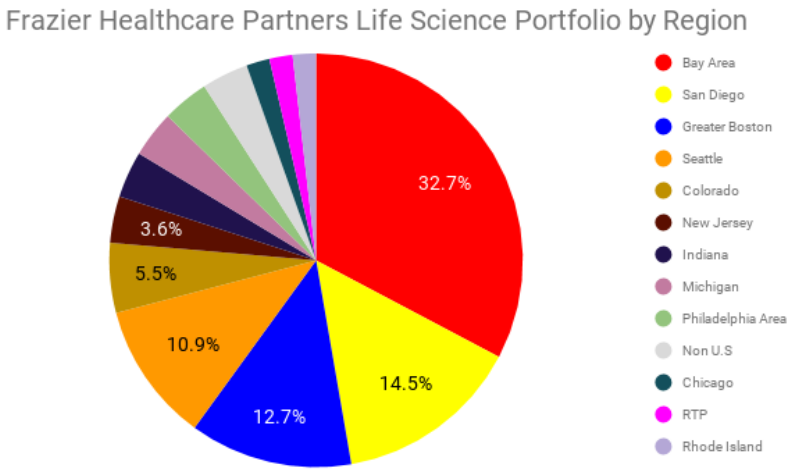

Figure 4: Percentage of companies in Frazier Healthcare Partners' life science portfolio by region, as of November 2017. The Bay Area (red) represents 32.7% of companies, San Diego (yellow) represents 14.5% and Greater Boston (blue) represents 12.7%. Seattle represents 10.9% of all companies.

New York VC firms exhibit a different investment pattern when they invest in U.S. life science companies. A quarter of the life science portfolio of Deerfield Management, the top VC firm in New York City, consists of companies based in the Bay Area, and 20% are based in the Greater Boston area (Figure 5). New York City

companies, however, only represented 4% of Deerfield's life science portfolio (Appendix G). To determine whether Deerfield's distribution pattern is similar in other New York City firms, the locations of the companies in the biopharmaceutical portfolio of OrbiMed, New York City's other VC firm ranked in the top 10 for U.S. biotechnology investment, were determined (Figure 6). The distribution pattern of the companies in OrbiMed's portfolio were similar to Deerfield's portfolio; 29% of the companies are based in the Bay Area, 20% are based in Greater Boston, and 8% are based in New York City (Appendix H).

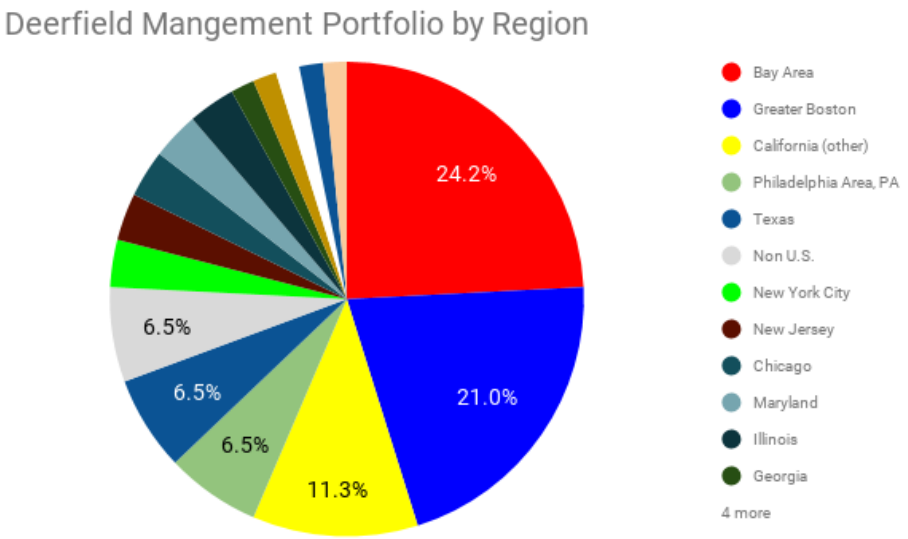

Figure 5: Percentage of companies in Deerfield Management's life science portfolio by region, as of November 2017. The Bay Area (red) represents 24.2% of all companies, Greater Boston (blue) represents 21%, and New York City (green) represents 4.26% of all companies.

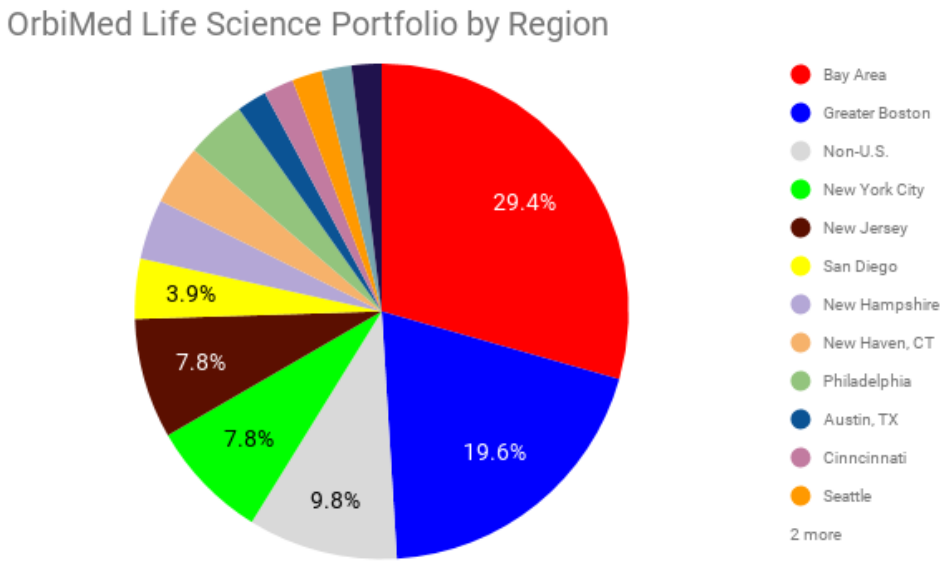

Figure 6: Percentage of companies in OrbiMed's biopharmaceutical portfolio by region, as of November 2017. The Bay Area (red) represents 29.4% of companies, Greater Boston (blue) represents 19.6%, non-U.S. regions (grey) represent 9.8% of companies and New York City represents 7.8% of all companies.

Entrepreneurial Culture within the Academic Institutions as Measured by the Output of Technology Transfer Offices

The Milken Institute collected the IP creation, licensing out, and start-up formation of U.S. university TTOs from 2012 to 2015, and used the metrics to rank the TTOs (DeVol, 2017). Columbia University was ranked second overall, Stanford was fifth, and MIT was ranked eighth (Table 7). In addition, New York University was ranked eleventh (DeVol, 2017).

Table 7: Top 10 University Technology Transfer Offices from 2012 to 2015

Rank	University
1	University of Utah
2	Columbia University
3	University of Florida
4	Brigham Young University
5	Stanford University
6	University of Pennsylvania
7	University of Washington
8	MIT
9	California Institute of Technology
10	Carnegie Mellon University

Location of TTO-Supported Start-Up Companies

A list of the start-up companies that were formed through the top TTO of each region were identified on each TTO's website, and the locations of the companies were identified. Almost all of the start-ups based out of the other university TTOs are located in the same region as the university. Start-up companies affiliated with Stanford University's Office of Technology Licensing (Appendix I) and MIT's Office of Technology Licensing (Appendix J) are all located in the Bay Area and Greater Boston, respectively. However, almost all of the start-up companies affiliated with universities in smaller life science clusters, University of Washington's CoMotion Labs (Appendix K) and North Carolina State University's Office of Technology Commercialization and New Ventures (Appendix L), are located in the Seattle area and near RTP, respectively. Half of the start-up companies listed in Columbia University's CTV are based in New York

City (Figure 7); the rest of the companies are located in established life science hubs or in Canada (Appendix M).

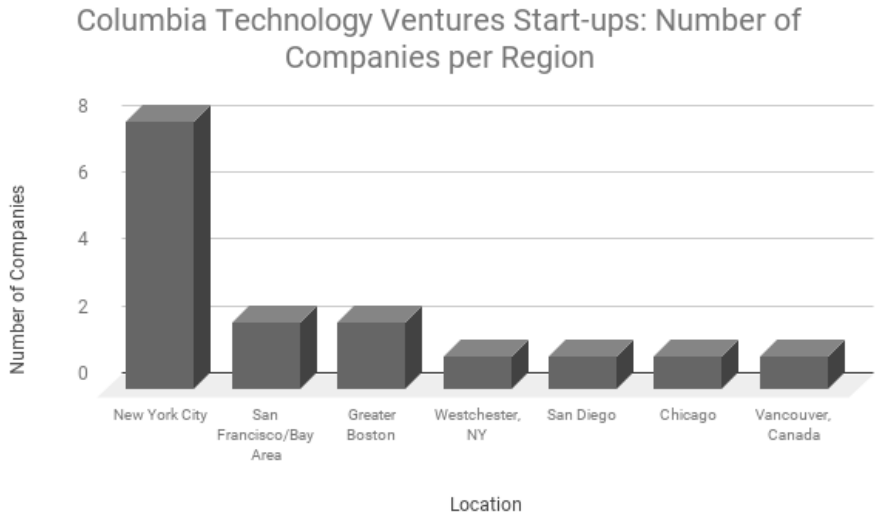

Figure 7: The number and location of start-up companies listed with the Columbia University's Technology Ventures.

Chapter IV

Discussion

According to Smilor (1989) and Fieldsteel (2013), successful technology clusters, such as life science clusters, require seven major segments that must interact with one another: research universities; large corporations; start-up companies; organizations that support the industry; and support from local, state and federal governments. However, according to various members of New York City's life science ecosystem, advocates for the development of the city's life science industry should focus on three main factors: increasing the availability of affordable lab space for start-up companies; increasing access to early-stage capital; and improving the entrepreneurial culture of research universities and institutions. The factors are mainly directed at start-up companies and research universities, although all seven segments can contribute to their improvement.

Lack of Affordable Lab Space

Leased Laboratory Space and Vacancy Rates

Even though New York City has the highest leased lab space price at $83 per square foot, the average price of leased lab space in Cambridge is also high. Kendall Square in East Cambridge is considered the biotech hub of Greater Boston due to the density and diversity of start-ups, large pharmaceutical companies, VC firms, and contract research organizations (Ledford, 2015). While there is 11.3 million rentable square feet of lab space in Cambridge (Alexandria, 2017), the vacancy rate is low and many start-ups are unable to afford lab space.

When start-ups do not have the capital to rent lab space in high demand areas like Manhattan and Kendall Square, or companies outgrow their current spaces and require a larger footprint, locating to a nearby suburb is a potential solution. For companies in Greater Boston, moving to the suburbs can be a disadvantage because they cannot regularly engage in the network that exists in Kendall Square. However, saving 41% in rental costs (Table 1) can be a major advantage, and the savings can be allocated towards research and business development. For start-up companies in New York City, renting lab space in Brooklyn would save 62% per square foot. Since a central life science hub has not been formally established in New York City, a start-up company in Brooklyn might not result in the same feeling of isolation when compared to Greater Boston companies who opt to lease space in the suburbs instead of in Kendall Square. However, most of the research universities and medical institutions are located in Manhattan, which is a disadvantage if a company needs to use facilities in an academic lab or collaborate with academic scientists.

Biotechnology Incubators

Incubators facilitate the growth and development of new, small businesses by providing space, administrative support, business expertise, shared resources, and opportunities to network (Mitra, 2012, p. 211). Biotechnology and life science incubators also provide lab-specific amenities such as lab benches, fume hoods, shared lab equipment, and biological waste management (Sia, 2015). They provide short term services for new companies, and most companies leave the incubator when they require more space or they are no longer commercially viable. Unlike traditional leased lab

spaces, many incubator tenants can sign monthly leases, and can lease a single lab bench in a shared lab space, which can decrease overhead costs. Access to lower cost lab space, shared lab equipment and business assistance can alleviate the burdens of starting a new life science company (Gura, 2015).

While incubator space can be a feasible, short term solution for start-up life science companies in New York City, there are barriers that exist. First, the lower cost creates a higher demand for the space; as a result, competition for theses spaces is high. For example, when Alexandria LaunchLabs opened, thirteen companies were selected out of a pool of 115 applications (Alexandria LaunchLabs, 2017). Second, the selection process acts as a barrier, especially for companies with ideas that are still in their initial stages. Third, incubators that are affiliated with large corporations or VC firms might have specific areas of research that they would like to incubate, which limits the types of start-up companies that are able to rent space. For example, BD Technology and Innovation Center in the RTP is interested in advanced diagnostics and genomic sciences (Becton, Dickinson and Company, n.d.).

Incubators are not always regarded as a worthwhile place to develop a biotechnology company. According to Dr. Eric Gordon, Partner at Skyline Ventures, incubators are "idealistic, designed for immature ideas that lack proof of principle and compelling stories. If you have the personnel to make [the idea] exciting and a good idea, you do not need an incubator because the idea can be pitched directly to a VC." (E. Gordon, personal communication, June 23, 2017).

Support for the Lack of Affordable Space

New York City has the highest leased lab space costs and the lowest vacancy when compared to the lab spaces in the Bay Area, Greater Boston, Seattle and the RTP. Many entrepreneurs are concerned with the availability and cost of start-up and medium-sized lab spaces. Biotechnology incubators, which are short-term alternatives for start-up companies, are not as expensive in New York City; many facilities cost less than incubators in Greater Boston. However, high demand, competition, and the criteria that incubators use to choose tenants hinder companies from renting the space.

Lack of Early Stage Capital for Life Science Companies

Funding is an essential component for the survival of life science companies, and VC firms provide a majority of the financial support for start-ups in the United States. In 2017, VC firms invested $14.4 billion into United States healthcare companies, which included the biotechnology, drug discovery, drug development, medical devices and disease diagnosis sectors. While the Bay Area and Greater Boston are the top two regions for healthcare VC deals in 2017, New York City is not ranked in the top five (PricewaterhouseCoopers, 2018a). However, the New York Metro area received over $11 billion in VC funding across all industries in 2017; the Bay Area is the only region that received more VC funding (PricewaterhouseCoopers, 2018b). According to Dr. Eric Gordon,

> New York City has the money [to invest in life science] but firms are more risk averse when investing in biotech. The money in drug discovery is so small, it is not a big enough priority. While New York City is the center of capitalism, people do not invest unless there is money to be made. (E. Gordon, personal communication, June 23, 2017).

Dr. John Diekman, Founding Partner at 5AM Ventures in San Francisco, has observed that New York City has other industries that are more attractive investments when compared to biotechnology (J. Diekman, personal communication, July 6, 2017). VC funding is available in New York City, yet it does not seem to be focused on biotechnology and life science.

Venture Capital Firms Investing in U.S. Life Science Companies

Since VC firms tend to invest locally, most VC firms that invest in biotechnology and life science would be expected to be located in the Bay Area and Greater Boston. Conversely, since VC investment in life science is not as prevalent in New York City, very few VC firms that invest in life science would be expected to be based in New York City. However, based on the data from EndPoints News, two of the top ten firms are located in New York City (Figure 1), and there are eleven VC firms in the top 100. Since there are top VC firms in New York City, there is VC capital available locally.

However, when the life science companies in the portfolios of the top VC firm in each region were identified, the results were unexpected. In the two established life science hubs, the expectation was that a majority of the portfolio companies would be local. While a large majority of the companies in Flagship Pioneering's therapeutics portfolio are located in Greater Boston (Figure 2), only 14% of the companies in New Enterprise Associates are located in the Bay Area (Figure 3). In Greater Boston, the increased presence of VC firms was due to the growth and development of the biotechnology and life science industry. On the other hand, in the Bay Area, VC firms existed locally even when the life science and biotechnology industry was at its infancy.

For many VC firms in the Bay Area, the life science industry has to compete with other industries, such as the technology industry, for VC capital. In addition, New Enterprise Associates has offices in the Bay Area, Boston, Maryland and New York City, which is reflected in the portfolio distribution.

VC firms in smaller life science clusters, such as Seattle and RTP, would be expected to invest in a mix of companies from the established hubs and their region. In Seattle, a majority of Frazier Healthcare's life science portfolio companies are based in the Bay Area and San Diego, which is not surprising because they are the two closest life science clusters (Figure 4). Aside from the Bay Area, San Diego and Greater Boston companies, Seattle companies represent the next highest percentage of companies represented in Frazier Healthcare's portfolio.

Deerfield Management and OrbiMed are two New York City based VC firms ranked in the top 100, according to EndPoints News. In both cases, almost half of the companies in their life science portfolios are based in either the Bay Area or Greater Boston (Figures 5 and 6). While this result is not surprising, the expectation is that the New York City VC firms would invest locally after investing in companies in established life science hubs. However, this is not the case. Deerfield Management invests in a higher percentage of companies located in other areas of California, Philadelphia and Texas than it invests in New York City companies (Figure 5). OrbiMed invests in a higher percentage of international companies than in New York City companies (Figure 6). In both cases, the New York City VC firms invest in less than 10% of companies located in their own region.

Support for the Lack of Early Stage Capital

The top VC firm rankings and the distribution of invested companies in various VC firm portfolios counter the perceived notion that VC firms prefer to invest locally. In addition, while there is a presence of VC firms that invest in life science in New York City, they either do not invest in local companies, or they invest in local companies and then relocate them to more established life science hubs. Either way, neither strategy will assist in the growth of New York City's life science cluster.

Entrepreneurial Culture within the Academic Institutions

The presence of an entrepreneurial culture in research universities and institutions is an important factor in the economic development of any industry that relies on innovation. Technology transfer from research institutions to the commercial sector plays a crucial role; from 1996 to 2013, IP licensing from universities and medical centers contributed $1.18 trillion to economic output in the United States (Pressman, 2017). As a result, technology transfer offices (TTO) act as gateways that influence the flow of scientific innovation through licensing; they can also provide assistance and resources to members of the academic community that want to form start-up companies based on their scientific discoveries.

Location of TTO-Supported Start-up Companies

TTOs can support entrepreneurs within their academic community by providing assistance and resources for start-up creation, such as physical office and lab space, access to start-up funding, and networking connections with experts and VC firms. If

these resources are local to the region, there is a strong likelihood that the companies will remain in the region over time. When compared to the other life science clusters, almost half of the life science start-up companies from the top TTO office in New York City do not remain in the region (Figure 7). One explanation could be that Columbia University and Columbia Technology Ventures lack the resources that other universities have. However, that does not appear to be true; Columbia Technology Ventures is affiliated with many programs, such as the Executives in Residence, Columbia Lab-to-Market Accelerator Network, and the Biomedical Accelerator. While Columbia University has been successful with licensing between 2012 to 2015 (DeVol, 2017), the institution is not prioritizing regional development as part of its strategy. The oversight of regional development also exists in other New York City TTOs. At the *EXOME* conference, Dr. Mike Foley, Director of the Tri-Institutional Therapeutics Discovery Institute (Tri-I TDI), a technology transfer partnership among Memorial Sloan Kettering, Rockefeller University and Weill Cornell Medical College, discussed successes when partnering twelve companies with their innovations within one year. However, when he was asked how many of the companies were based in New York City, he admitted that none of the companies were located in the city (Foley, 2017).

Support for the Lack of Entrepreneurial Culture within Academic Institutions

Based on the Milken Institute's university TTO rankings, New York City has the second and the eleventh best university TTOs in the United States, which indicates that universities in New York City successfully license their scientific discoveries to companies. The university TTOs in New York City also demonstrate their entrepreneurial

culture through the formation of start-up companies and the resources they provide to aspiring entrepreneurs within their academic community. Analysis of the start-up companies from Columbia Technology Ventures revealed that almost half of the companies are located outside of New York City. While New York City TTOs exhibit an entrepreneurial culture, regional development does not necessarily play a major role in that culture.

Relocation of New York City Life Science Start-up Companies

The location of life science start-up companies supported by New York City VC firms either indicates that VC firms in New York City do not invest locally, or they relocate companies to the Bay Area or Greater Boston because they are established life science hubs. The location of Columbia University's life science start-up companies reveals that the companies do not remain in New York City, instead, they relocate to other life science clusters. The relocation of companies from New York to another region is not a new phenomenon; Romanelli and Feldman analyzed the formation and relocation of U.S. biotherapeutic companies from 1976 to 2003. From 1976 to 1986, the New York metro area had many start-up companies. However, New York experienced the most relocation of entrepreneurs and companies from New York to other life science clusters from 1987 to 2003. In addition, the outflux of talent and companies was not replaced with the formation of new start-up companies (Romanelli, 2006, pp. 106-107). As a result, New York City lost a portion of their life science management talent, and this loss reverberates into their current life science ecosystem.

While the reasons for the outflux of companies and entrepreneurs between 1987 to 2003 were not fully known, Romanelli and Feldman hypothesized that the culture of large pharmaceutical companies that were near New York played a role in stifling the entrepreneurial environment in the region (Romanelli, 2006, p. 109).

Life Science Talent in New York City

Due to the prestigious research universities and medical centers that are located in New York City, the city does not lack scientific and other technical talent. On the other hand, the relocation of life sciences companies from New York City to more established life science hubs from 1987 to 2003 has resulted in the loss of management talent. The lack of lab space and VC equity directed at local companies contributed to this loss. According to Hugh Rienhoff:

> One of the most important factors [of a successful biotech cluster] is success: if there is a successful company that grows to be a real powerhouse, many people "train" there and then leave for more responsibility, more stock and a crack at doing their own thing. Genentech alumni have probably started 100 companies. One successful company can provide a source of management for a lot of new companies. It is not the same with big pharma because most people in big pharma are not entrepreneurial or are not in an entrepreneurial area so they do not have that option. (H. Reinhoff, personal communication, June 20, 2017).

Since life science companies in New York City lacked the infrastructure and funding to develop, life science companies moved out of the city and management talent was not able to develop locally. New York City did not only lose management talent that could have transitioned into entrepreneurs that form start-up companies, they lost local mentors who could provide guidance for inexperienced management talent (Zokowski, 2012). As New York City strives to develop its private sector life science ecosystem, solutions to cultivate local management talent should be considered.

Chapter V

Case Studies

This chapter uses the case study approach to compare the ways that two life science companies in New York City are attempting to survive and operate when compared to a life science company in Greater Boston.

Disruption in the Life Science Industry

To succeed in any environment, businesses need to adapt to the industrial landscape and to the opportunities and setbacks afforded to them by their regional ecosystem. The life science sector demonstrates these adaptations—for example, large pharmaceutical companies have reduced in-house R&D to mitigate the high costs and losses that often accompany drug and therapeutic development. Since R&D activity is reduced, larger building spaces for labs and other research-related facilities are no longer required. As another example, educated professionals prefer to live in urban areas over suburban or rural areas, which is reflected in the migration of corporate headquarters from the suburbs to urban centers (Katz, 2014). For example, in the past few years, pharmaceutical companies have been relocating from New Jersey to Greater Boston or the Bay Area (Tucker, 2013).

While larger pharmaceutical companies can afford the higher prices of urban real estate, smaller companies are not always as fortunate. However, smaller companies often want to remain proximal to large companies, in hopes of forming partnerships or mergers and acquisitions (M&A). This poses a challenge for smaller life science companies—how

can they geographically position themselves so they can successfully develop their products and leverage relationships with other companies, yet remain financially viable despite high development costs and overhead. Thus, this requires its own type of adaptation, such as disruptive innovation. Clayton Christensen defined disruptive innovation as strategies used by smaller companies to challenge established companies and capture market share (Christensen, 2015).

Millennium Pharmaceuticals

Life science companies, such as Millennium Pharmaceuticals, have attempted to disrupt the usual manner in which therapeutics are discovered for various reasons; these changes could save money, speed up the development and approval of their therapies, or give the companies competitive advantages that could increase their odds of survival (Kapeller, 2016). Mark Levin founded Millennium Pharmaceuticals in 1993 to disrupt the established manner in which drugs were developed, by developing treatments based on the gene targets discovered through the Human Genome Project. Levin attempted to use genomics to increase the pace at which gene targets were found, and drug candidates were screened and discovered (Thomke, 2001). The idea appealed to many existing companies; within five years, Millennium formed partnerships with Roche, Eli Lilly, Wyeth-Ayerst and Bayer AG. They also created two subsidiaries, Millennium Biotherapeutics and Millennium Predictive Medicine; each subsidiary's purpose was to focus on a particular subset of products (Watkins, 2003). While Millennium Pharmaceuticals was progressing financially and drawing interest, the company lacked experienced leadership and an organized, forward-thinking business plan, which caused

issues as their company expanded (Thomke, 2001). Millennium Pharmaceuticals was ultimately unable to disrupt the drug development process through genomics, and was acquired by Takeda in 2008 (Gibbs, 2008). However, in the twelve years Levin was CEO, Millennium developed several drugs, not based on their genomics technology aimed at finding gene targets, but by acquiring drugs through partnerships and acquisitions (Pollack, 2005). While Millennium's strategy failed, they stayed true to their goal of developing new medicines that acted on novel, innovative targets.

Life Science Company Disruption in New York City

According to the NYCEDC, there are 120 life science companies in New York City (2018). Large companies, such as Pfizer and Bristol-Myers Squibb, have their corporate headquarters in New York City and other branches of their company in other locations. Some companies have disrupted the paradigm of drug and therapeutic development in a novel manner. Some New York City companies have adopted the parent and subsidiary, or hub and spoke, biotechnology model. The parent, or hub, company develops or acquires IP or therapeutic candidates that is later transferred to a subsidiary, or spoke, company, in exchange for equity or other forms of payment (Comeau, 2012). Two New York City based companies, Roivant Sciences and Fortress Biotech, have adopted disruptive parent and subsidiary approaches (Figure 8).

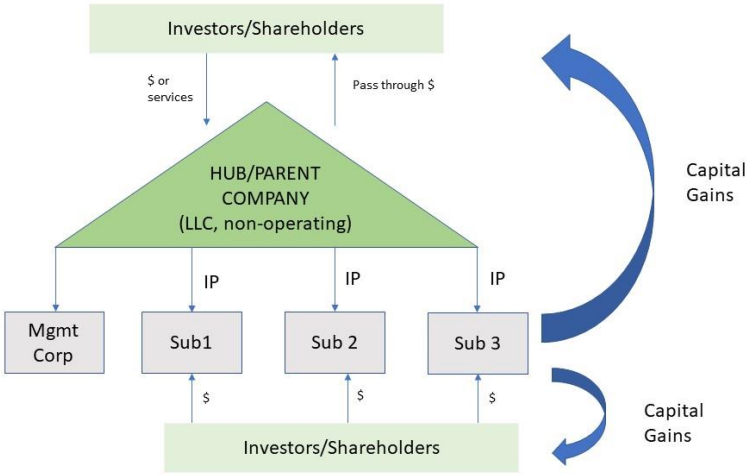

Figure 8: Diagram of the parent and subsidiary, or hub and spoke, biotechnology company model. Investors provide capital for the parent company, which acquires IP. The management corporation (Mgmt Corp) is responsible for management of the hub company, hiring executive employees for subsidiaries (Sub1, Sub2 and Sub3), and handling management service agreements. Investors and shareholders can also invest in individual subsidiaries. Capital gains are given to individual investors and to investors of the parent company, since the parent company usually has equity in the subsidiaries. The management service agreement fee that subsidiaries pay the parent company is not included in this diagram. Adapted from Keiper (2016).

Roivant Sciences

Roivant was founded in 2014 by Vivek Ramaswamy, a former hedge fund analyst at QVT Financial. He was not considered a typical biotechnology company CEO; he started the company at the age of 28, without any prior experience in biotech leadership or graduate-level scientific training (Loizos, 2017). Ramaswamy's method of disrupting the life science industry was to create platforms around drugs and therapies that other companies were no longer interested in developing (Ramaswamy, 2017). Once a drug candidate was acquired, a subsidiary was created as a development vehicle for the candidate; their first and perhaps most infamous subsidiary was Axovant, a New York

City company which was formed after Roivant purchased Intepirdine, a potential drug for Alzheimer's disease, from GlaxoSmithKline for $5 million (Adams, 2018). Roivant has a total of six subsidiary companies that focus on issues such as skin disease, women's health and rare diseases. Ramaswamy's vision and Roivant's business model convinced many to invest in the company; for example, Roivant raised $1.1 billion from Softbank Vision Fund and Dexcel Pharma (Herper, 2017). In addition, Axovant's initial public offering (IPO) in 2015 raised $315 million six months after the subsidiary was created; and Myovant, another Roivant subsidiary, raised $218 million with their IPO in 2016 (Lawrence, 2016).

Despite Roivant's financial success, there was skepticism around the company's vision to transform the drug and therapeutic industry. Adam Feuerstein, a former biotech journalist with TheStreet and current journalist at STAT news, noted that the financial activities surrounding Axovant's IPO seemed nefarious, especially since the activity was based on a drug that GlaxoSmithKline deemed ineffective based on numerous trials (2015). Over time, Feuerstein's skepticism was validated; Intepirdine failed Phase III trials for Alzheimer's disease (Axovant, 2017a), and failed Phase II/IIb trials for dementia with Lewy Bodies, or DLB (Axovant, 2018a).

While Axovant originally announced they observed positive results for the DLB drug Nelotanserin (Axovant, 2018a), which was acquired through a partnership with Arena Pharmaceuticals (n.d.), they later realized their data was incorrectly reported and their results for Nelotanserin were actually negative based on their p-values (Axovant, 2018b). In February 2018, Axovant's CEO, COO and three board of directors resigned from the company (Axovant, 2018c). Roivant remains true to their strategy of identifying

value in drugs that large pharmaceutical companies believed to be failures. While their model will be able to produce financial success, they might not be able to achieve clinical success.

Fortress Biotech

Fortress Biotech is another New York City based life science company that operates through the parent and subsidiary model. The company was formed in 2006, as Coronado Biosciences. Coronado became a public company in 2011; at the time, its lead therapy was CNDO-201, a potential treatment for Crohn's disease, which contained eggs from a porcine parasite (Weintraub, 2011). In October 2013, Phase II trial results for *Trichuris suis* ova (TSO, or CNDO-201) did not show any improvement in the treatment of Crohn's disease (Coronado Biosciences, 2013a). Two months later, Dr. Lindsay Rosenwald was named as the new CEO as part of a management reorganization (Coronado Biosciences, 2013b). By 2015, Coronado Biosciences had transformed into a completely different type of company. Five subsidiaries were created: Journey Medical Corporation, which focused on dermatology products (Coronado Biosciences, 2014); Avenue Therapeutics, which focused on intravenous tramadol (2015); Checkpoint Therapeutics, which focused on cancer-targeting antibodies (Coronado Biosciences, 2015a); Mustang Bio, which focused on chimeric antigen receptor (CAR-T) treatments (Coronado Biosciences, 2015b); and Diavax Biosciences (now known as Helocyte), which focused on therapies for cytomegalovirus (Coronado Biosciences, 2015c). In addition, Coronado changed its name to Fortress Biotech to reflect the changes in their company structure (Coronado Biosciences, 2016c). As of 2018, Fortress Biotech owns 11

subsidiary companies, and most are headquartered on the same floor of the New York City building occupied by Fortress.

Implications of the Parent and Subsidiary Model in New York City

A parent and subsidiary corporate model has many advantages from a company perspective. Forming subsidiaries based on disease or therapeutic technology attracts a variety of investors that only have to invest in one particular platform instead of the entire array of potential therapies (Comeau, 2012). In addition, while the subsidiaries mainly focus on developing their therapeutic platform, the parent company can focus on areas such as fundraising and IP procurement. As a result, the subsidiary company can recruit management talent that is best suited for their disease target or therapeutic technology (Ernst and Young, 2017).

There are also many financial advantages to a parent and subsidiary model, at least from the parent company's perspective. Roivant holds a large share of equity in each subsidiary and quickly pushes their subsidiaries towards lucrative IPOs to gain financial revenue (Lawrence, 2016; Feurstein, 2017). While Fortress also owns equity in each subsidiary, Fortress' subsidiaries pay Fortress an annual consulting fee of $500,000 (Checkpoint Therapeutics, 2015; Mustang Bio, 2016). The parent company reaps financial and reputational benefits during the IPO of their subsidiaries and announcements of their subsidiaries' positive milestones and clinical trial results, yet they might not share the same financial and reputational losses when their subsidiaries experience negative clinical trial results.

For example, when Intepirdine failed Phase III clinical trials for Alzheimer's, Axovant's stock price fell from $24.50 to $6.33 (Axovant, n.d.). Despite this setback, Roivant was still able to form development deals with HanAll Biopharma and AstraZeneca (Axovant, 2017b). When Intepirdine failed Phase II/IIb clinical trials for dementia with Lewy Bodies disease, David Hung, the CEO resigned (Axovant, 2018c), despite the fact that Roivant, not Hung, had decided to acquire Intepirdine from GSK, with clear indications that the drug was unlikely to treat Alzheimer's (Lowe, 2017).

Parent and subsidiary life science companies are not exclusive to New York City. For example, BridgeBio is a parent and subsidiary company in Palo Alto (Vinluan, 2017), and Nimbus Therapeutics is based on Cambridge (Keiper, 2016). However, in the Bay Area and Greater Boston, the two top life science clusters in the U.S., parent and subsidiary life science companies are interspersed with established pharmaceutical companies, large biotechnology companies, medium-sized biotechnology companies and entrepreneurial start-ups. With a large variety of life science companies in the Bay Area and Greater Boston, managerial and scientific talent can migrate from one company to another.

In established life science clusters, managerial talent can gain experience with different areas of the therapeutic development pipeline. Managerial talent at start-up companies will learn about the resources and capabilities needed to push a potential therapy from the discovery stage to the pre-clinical stage. Smaller companies, limited by the number of employees, managers tend to learn skills outside of their initial job role, and scientists are sometimes given the opportunity to learn about the business portion of the company as well. Management in larger companies that tend to acquire drug and

therapeutic candidates after the pre-clinical stage will gain valuable experience with the clinical trial process.

On the other hand, in New York City, a majority of the life science companies are corporate headquarters for large pharmaceutical companies, with a growing number of parent and subsidiary companies. Since parent life science companies tend to acquire later-stage drug and therapy candidates for their subsidiaries, the younger managers in these companies will only gain experience with the latter end of the therapeutic development process. If New York City only accommodates parent and subsidiary companies, the management talent will lack the breadth of management experience that their counterparts in the Bay Area and Greater Boston have.

Most research at parent and subsidiary companies is contracted to external entities as a cost cutting measure. While outsourcing lab research might be advantageous for New York City life science companies due to the lack of lab space, there are also disadvantages for the city's regional life science industry. Scientific talent may be abundant in New York City, but if life science companies do not have in-house R&D facilities, this will result in the outward migration of scientific talent into more established life science hubs.

Life science companies that focus on later-stage drug and therapy candidates do not always have a scientific advisory board. For example, out of Roivant's six subsidiaries, Datavant is the only subsidiary with a scientific advisory board (SAB), and two of the twelve members of the SAB are academic scientists (Datavant, n.d.) Academic scientists on SABs often play major roles in recruiting and interviewing early-stage scientists for employment (Audretch, 2001). Without this key connection, early-stage

scientists in New York City are less likely to find employment in later-stage life science companies, and scientists outside of New York City are less likely to move into the city.

The approach of creating parent and subsidiary companies is one example of a disruptive strategy used by smaller life science companies in New York City. Roivant Sciences and Fortress Biotech have adapted to the lack of resources in New York City by eliminating or reducing the need for scientific personnel and lab space, obtaining therapies that are in the latter stages of drug discovery, and by obtaining capital funding by investors that prefer short term gains over the long-term commercialization of therapeutics. While this disruptive approach can be beneficial to the individual company, it does not develop local managerial or scientific talent, which will ultimately hinder the development of New York City's life science industry.

Chapter VI

Recommendations

This chapter outlines recommendations for the New York City life science industry based on the tested three hypotheses and case studies examined in this thesis.

Overview

As New York City moves forward with the initiative to create a world class life science hub, policy makers and the private sector must work together to create a vision of what types of companies should proliferate in the region. Lab space and wet lab incubator space was more expensive in New York City than in the established hubs, Greater Boston and the Bay Area. In addition, New York City has a lower lab vacancy rate than the established hubs. New York City has top VC firms in the city, but the firms do not invest in local companies. While university and medical institution TTOs have created strategies and partnerships to advance academic research closer to the pre-clinical stage and license IP, many of the spin-off start-up companies are located outside of New York City.

The lack of affordable lab space is a clear obstacle that is hindering the growth of New York City's life science industry, although established life science hubs are experiencing similar issues. Lab space prices and vacancy rates in Cambridge are almost as high as New York City's rates; Cushman and Wakefield have reported that lab rental prices are approximately $80 per square foot, and vacancy rates are 0.6% in East Cambridge (2017). On the other hand, New York City is not lacking VC firms or TTOs with entrepreneurial mindsets. Since local VC firms and TTOs are focusing on the development of successful start-up life science companies, local economic development

is not a priority for them. If VC firms and TTOs could benefit from incentives that locate or re-locate companies in New York City, they would be more likely to consider New York City as a viable location for their companies.

Recommendation One: Need for Increased Lab Space

The recommendation to increase the amount of lab space in New York City is not novel, since many local economic development organizations have noted the necessity for space. New York State's initiative addresses lab space by providing grants for lab space, tax-free land for lab space at academic institutions, and investing in JLabs, which is a lab incubator sponsored by Johnson & Johnson innovations. New York City's initiative allocates funds for incubators and an Applied Life Sciences Hub, as well as tax incentives for commercial lab space. In January 2018, the NYCEDC announced a call for proposals to develop the $100 million Applied Life Sciences Hub, with three suggested locations: East Harlem; near the Alexandria Center for Life Science in Kips Bay; and Long Island City, Queens (Philippidis, 2018).

Commercial buildings designed for lab space should take into account two main factors: mixed-use space and opportunities for interaction and networking. While lab incubators can be beneficial for start-up life science companies, they are not suitable for medium-sized companies. While the growth of New York City's life science ecosystem depends on start-up companies, the growth should also ensure that medium-sized companies remain in the city as they expand. The management and scientific talent in the medium-sized companies have gained valuable experience and understand the New York City life science industry; they are assets to the life science ecosystem. The ideal lab

building would have a lab space that can be leased by one company or shared by multiple companies, as well as incubators where start-up companies can rent a lab bench or a small lab room. To encourage long-term tenancy in the building, building owners and management can offer discounts to incubator tenants if they choose to lease lab space once their company expands.

Networking and informal interactions are necessary for the development of any life science ecosystem. Increasing interactions in the commercial sector of the life science industry in New York City is an important way to share information, potentially collaborate with local partners and gain knowledge from more experienced members of the life science community. When buildings are constructed or renovated as lab spaces, there should be a conscious effort to include common areas where employees from different companies can gather, interact and learn. One example of a building designed for collaborative interaction is the AstraZeneca Gatehouse park BioHub in Greater Boston. The building has open meeting areas, including complimentary coffee and snack areas where employees can interact, and conference areas where seminars and social events are held (AIM Video Library, 2016). Constructing an analogous space in New York City might be more challenging; since space is limited, buildings are taller, which reduces the opportunity for accessible common spaces. However, building owners should attempt to implement common areas for interaction.

Location of lab spaces also plays an important role in the development of New York City's life science industry. NYCEDC has narrowed the location of the Applied Life Sciences Hub to three places; out of the choices, the location in Kips Bay would be the best choice. While Kips Bay is more expensive than East Harlem and Long Island

City, the Alexandria Center for Life Sciences and NYU Langone Medical Center are located in the same area. Other medical centers and institutions, such as Rockefeller University and Mount Sinai are located on the east side of Manhattan as well, which would reduce commuter time if travel to or from the institutions is required.

New York City commercial rental prices are high. Residential rental prices are also high; potential management and scientific talent might not consider moving or staying in New York City due to high apartment prices. As of February 2017, the average rental cost of a two-bedroom apartment is over $5,500 per month in New York City (RentCafe, 2017a); for comparison, the rental cost of a two-bedroom apartment is approximately $3500 in Cambridge, Massachusetts (RentCafe, 2017b). Lab incubators, such as LabCentral, often have corporate partners that fund annual tenancy rates for a selected group of start-up companies that have promising research platforms. Private incubators should consider corporate partnership that funds all or a portion of the annual residential rent costs for the founder or CEO of a start-up company that locates their company in New York City. The rental subsidies would alleviate some of the cost of living issues that often arise when living in expensive cities, and give the company founders the opportunity to focus on the development of their companies.

Recommendation Two: More VC and TTO Incentives Will Locate Companies in New York City

While New York City and State incentives offer tax credits for companies in New York City, there are not any incentives for VC firms and TTOs when determining where start-up companies are located. VC firms and TTOs will implement measures to ensure

their companies become financially viable for their return on investment. TTOs are motivated to locate their start-up companies where they are most likely to succeed because any payments from the company to the TTO, either through licensing, milestone payments or royalties once the therapeutic is commercialized, are allocated towards TTO operational costs. Since 87% of TTOs do not break even, the pressure for their start-ups to succeed is even higher (Valdivia, 2013).

The New York City government should earmark funding for VC firms and TTOs. The city government should create grants that are directed at TTOs, which would be awarded to TTOs that spin-off start-up companies that remain in New York City for five years. While five years is a long time to wait for a grant, it would provide funding for the TTO on top of milestone payments from the company. VC firms are less likely to be influenced by grants, since they have raised their own capital to invest in start-up companies. Public-private fund partnerships might influence VC firms to invest locally, as long as the funds are earmarked for life science companies that remain in the city for a number of years. In 2015, New York City, through the NYCEDC, founded the City of New York Early-Stage Life Sciences Funding Initiative, a $150 million public-private fund with Flagship Pioneering and Arch Venture Partners (Fidler, 2015). While the fund was created to provide capital for up to twenty life science start-up companies in New York City, the current recipients of the fund are not known. In addition, the VC firms that have partnered with NYCEDC are headquartered in Cambridge and Chicago, respectively. Any future public-private funds for start-up life science companies should include local VC firms, such as Deerfield and OrbiMed.

Increased Affordable Lab Space Will Discourage the Parent and Subsidiary Model

The case studies of Roivant Sciences and Fortress Biotech demonstrated that life science companies in New York City have implemented two strategies to remain operational in New York City. Many companies are virtual biotechnology companies that outsource their R&D and clinical operations. Roivant and Fortress Biotech are also parent companies with numerous subsidiaries. While the operation of a virtual company results in cost savings and allows companies to operate in the absence of affordable lab space, virtual companies do not contribute to the local life science ecosystem, nor do they contribute to the commercialization of new therapeutics. A successful life science industry consists of companies of different sizes, which allows for movement of management and scientific talent with the ecosystem. Virtual companies limit the size of companies, and limit the movement of talent. In addition, in-house R&D can perform due diligence and validate scientific findings before they move forward with research and drug discovery; since virtual companies do not have internal R&D, they might miss red flags that would impede the progress of their potential therapeutic (Lyman, 2012).

Parent and subsidiary companies also slow the development of New York City's life science industry. Since the subsidiaries focus on clinical stage research, their management teams are not exposed to the early stages of therapeutic discovery; as a result, they are less equipped to lead local start-up companies that focus on discovery. Scientific talent, which is abundant in New York City, face higher barriers to employment in parent and subsidiary companies due to the lack of internal R&D conducted in the companies. In addition, parent companies tend to be focused on a

financial return on investment through acquisitions or IPOs rather than the commercialization of the potential therapeutics they have acquired for development.

The development of affordable lab spaces in New York City will promote the formation of start-up companies that can conduct internal R&D. In addition, the presence of medium-sized companies will enhance the availability of experienced management talent for the city's life science ecosystem. However, a cultural shift must also occur. The New York City life science industry might not have the patience to allow their ecosystem to flourish in the manner that Greater Boston or the Bay Area have flourished. Greater Boston became a life science hub over the past ten years due to the infrastructural improvements that were funded by state initiatives. As lab and residential real estate prices continue to rise in the Greater Boston, New York City has the opportunity to attract life science companies to their region; however, they have to promote the integration of traditional companies that require lab space for their operations rather than virtual or parent and subsidiary companies that prefer rapid returns on investment over therapeutic commercialization.

Chapter VII

Conclusion

While New York City has a developing life science cluster that has recently been bolstered by state and city initiatives, there are three obstacles that are impeding the industry's development. First, the high lab rental costs and low occupancy rate, when compared to other life science hubs and clusters, pose a barrier for companies that want to form or expand their companies in New York City. Second, local life science VC capital is not directed at companies in New York City; even if the scientific discoveries are based in New York City, VC firms tend to relocate firms to other life science clusters due to cost or availability of resources. Third, TTOs in New York City do not prioritize the local formation of life science companies.

Despite the three obstacles, life science companies exist in New York City. Through the case study approach, the operations of Roivant Sciences and Fortress Biotech revealed that both companies use the parent and subsidiary company model to develop preclinical or clinical stage therapeutic candidates. The virtual biotechnology model adopted by parent and subsidiary companies does not address the lack of management talent in New York City, nor does it promote the growth of the city's life science ecosystem.

The growth of New York City's life science industry, and its promotion from a developing cluster to a viable hub, will depend on increased availability of mixed-use lab spaces that incorporate opportunities for informal and formal interactions and networking. Government grants and public-private funds can motivate VC firms and TTOs to invest locally. Cost of living subsidies, offered through corporate sponsors at

private incubators, can convince management and scientific talent to remain in New York City despite high residential real estate costs.

However, the growth of New York City's life science industry will not occur without a shift in entrepreneurial culture. New York City is known as the city that never sleeps; as a result, patience is minimal. Investors often seek a rapid return on investment; unfortunately, therapeutic development does not align with a rapid return on investment, since it can take fifteen or more years to commercialize a therapeutic product. New York City must balance virtual companies and parent and subsidiary companies with traditional life science companies that value the development and commercialization of therapeutic products over quick financial gains. Otherwise, the New York City life science cluster will not be able to compete with Greater Boston and the Bay Area.

Appendix A

North American Industry Classification System (NAICS) Codes Corresponding to Employment in the Life Sciences

NAICS Code	Occupation	Percentage of Total Occupation in the Life Science Industry
3254	Pharmaceutical manufacturing, including biologics	100%
541711	R&D in biotechnology	100%
541712	R&D in physical, engineering and life sciences (except biotech)	22%
334516	Analytical laboratory instrument manufacturing	30%
54138	Testing laboratories	9%
622	Hospitals	4.5%
61131	Universities	1.9%
621511	Medical testing laboratories	100%

Data adapted from the Massachusetts Biotechnology Council (Steele, 2017).

Appendix B

List of Research Universities and Medical Institutions in New York City

Albert Einstein College of Medicine

Columbia University – Morningside Heights Campus

Columbia University Medical Center (and Medical School)

Icahn School of Medicine at Mount Sinai Hospital

Memorial Sloan-Kettering Cancer Center

NYU Medical Center (and Medical School)

SUNY Downstate Medical School

The Rockefeller University

Weill Cornell Medical College

Appendix C

Top Ten VC Firms that Invest in U.S. Biotechnology

VC Firm	Region	Rank in 2016	2016 Total Equity Invested ($ Millions)
Flagship Pioneering	Greater Boston	1	261.83
Third Rock Ventures	Greater Boston	2	170.57
New Enterprise Associates Inc.	Bay Area	3	146.11
Arch Venture Partners LLC	Chicago	4	131.18
Venrock Inc.	Bay Area	5	118.78
Deerfield Management Company LP	New York	6	115.51
OrbiMed Advisors LLC	New York	7	104.79
Atlas Venture Advisors Inc.	Greater Boston	8	92.42
Gurnet Point Capital LLC	Greater Boston	9	92
5AM Ventures LLC	Bay Area	10	90.47

Data was adapted from EndPoints News (Carroll, 2017).

Appendix D

Flagship Pioneering Therapeutics Portfolio: Number of Companies per Region.

Region	Number of Companies	Percentage
Greater Boston	27	81.82%
Bay Area	1	3.03%
California (Other)	1	3.03%
Michigan	1	3.03%
Connecticut	1	3.03%
Pennsylvania	1	3.03%
Non-US	1	3.03%

Names of companies were obtained from Flagship Pioneering (n.d.)

Appendix E

New Enterprise Associates Biopharma Portfolio: Number of Companies per Region.

Region	Number of Companies	Percentage
Greater Boston	15	23.44%
Bay Area	9	14.06%
Non-U.S.	9	14.06%
Maryland	8	12.50%
California (Other)	4	6.25%
Pennsylvania	4	6.25%
North Carolina	4	6.25%
New Jersey	3	4.69%
Colorado	3	4.69%
Texas	2	3.13%
Georgia	1	1.56%
Massachusetts (other)	1	1.56%
Michigan	1	1.56%

Names of companies were obtained from New Enterprise Associates (n.d.)

Appendix F

Frazier Healthcare Partners Life Science Portfolio: Number of Companies per Region.

Region	Number of Companies	Percentage
Bay Area	18	32.73%
San Diego	8	14.55%
Greater Boston	7	12.73%
Seattle	6	10.91%
Colorado	3	5.45%
New Jersey	2	3.64%
Indiana	2	3.64%
Michigan	2	3.64%
Philadelphia Area	2	3.64%
Non-U.S.	2	3.64%
Chicago	1	1.82%
RTP	1	1.82%
Rhode Island	1	1.82%

Names of companies were obtained from Frazier Healthcare Partners (n.d.)

Appendix G

Deerfield Management Life Science Portfolio: Number of Companies per Region.

Region	Number of Companies	Percentage
Bay Area	15	31.91%
Greater Boston	13	27.66%
California (other)	7	14.89%
Philadelphia Area, PA	4	8.51%
Texas	4	8.51%
Non U.S.	4	8.51%
New York City	2	4.26%
New Jersey	2	4.26%
Chicago	2	4.26%
Maryland	2	4.26%
Illinois	2	4.26%
Georgia	1	2.13%
Colorado	1	2.13%
Missouri	1	2.13%
Florida	1	2.13%
Washington	1	2.13%

Names of companies were obtained from Deerfield Management (n.d.)

Appendix H

OrbiMed Biopharmaceutical Portfolio: Number of Companies per Region.

Region	Number of Companies	Percentage
Bay Area	15	29.41%
Greater Boston	10	19.61%
Non-U.S.	5	9.80%
New York City	4	7.84%
New Jersey	4	7.84%
San Diego	2	3.92%
New Hampshire	2	3.92%
New Haven, CT	2	3.92%
Philadelphia	2	3.92%
Austin, TX	1	1.96%
Cincinnati	1	1.96%
Seattle	1	1.96%
Maryland	1	1.96%
Milwaukee	1	1.96%

Names of companies were obtained from OrbiMed (n.d.)

Appendix I

Location of Stanford University's Office of Technology Licensing Start-up Companies

Nine out of nine companies are located in the Bay Area.

Company Name	Location
Alexo	San Francisco
BluePrint Genetics	San Francisco
Capp Medical	Saratoga, CA
Circuit Therapeutics	Menlo Park, CA
Globavir	Los Altos & Palo Alto
Oculeve	San Francisco
Probiusdx	El Cerrito, CA
Selten Pharma	San Carlos, CA
Verinata Health	Redwood City, CA

Names of companies were obtained from Stanford University Office of Technology Licensing (2016, 2016 March).

Appendix J

Location of MIT's Office of Technology Licensing Start-up Companies

Nine out of nine companies are located in the Greater Boston Area.

Company Name	Location
Alnylam	Cambridge
Arch Therapeutics	Framingham, MA
ImmuneXcite	Lexington, MA
Kytopen	Cambridge
Momenta	Cambridge
Pervasis Therapeutics	Cambridge
Springleaf Therapeutics	Boston
Suono Bio	Cambridge
Taris Biomedical	Lexington, MA

Names of companies were obtained from MIT Deshpande Center for Technological Innovation (n.d.)

Appendix K

Location of University of Washington's CoMotion Labs Start-up Companies

Sixteen out of eighteen companies are located in the Seattle Area.

Company Name	Location
Aortica	Bellevue, WA
Aqueduct Neuroscience	Bothell, WA
Artemesia Biomedical	Sammamish, WA
Attodx	Seattle
Beat Biotherapeutics	? (No address listed)
CisThera	Kirkland, WA
Cyrus Biotechnology	Seattle
Ennaid Therapeutics	Alpharetta, GA
Epithany	Seattle
Healionics	Redmond, WA
Impel Neurophamra	Seattle
Kitotech Medical	Seattle
Nanosurface Biomedical	Seattle
Oricula Therapeutics	Seattle
PVP Biologics	San Diego and Seattle
Resolve Therapeutics	Seattle
Stella Therapeutics	Seattle
Veravanti	Redmond, WA

Names of companies were obtained from University of Washington CoMotion Labs. (n.d.)

Appendix L

Location of North Carolina State University's Office of Technology Commercialization and New Ventures Start-up Companies

Ten out of twelve companies are located in North Carolina.

Company	Location
AlphaVax Inc.	RTP
Arbovax	Raleigh, NC
Biomarck Pharmaceuticals	Durham, NC
BioResource International	Durham, NC
Clave Biodesign	Cary, NC
Locus Biosciences	Morrisville, NC
MAA Laboratories Inc.	Raleigh, NC
Nanvactor	Raleigh, NC
Origen Therapeutics	Emeryville, CA
Rise Therapeutics	Rockville, MD
Sirga Advances Biopharma	RTP
Trana Discovery	Cary, NC

Names of companies were obtained from NC State University Office of Technology Commercialization and New Ventures. (n.d.)

Appendix M

Location of Columbia University's Technology Ventures Start-up Companies

Six out of sixteen companies are located in New York City.

Company Name	Location
ALSP	La Jolla, CA
Applied Therapeutics	New York City
Bidesy	San Francisco
Caelum	New York City
Darwin Health	New York City
East River Biosolutions	New York City
Epibone	New York City
Genia	Mountain View, CA
InVivo Analytics	New York City
Kallyope	New York City
Levo Therapeutics	Chicago
Mesoblast	New York City
Proterris	Boston
Sapience Therapeutics	Harrison, NY
TheraPten Biosciences	Kelowna, BC, Canada
Vor Biopharma	Boston

Names of companies were obtained from Columbia Technology Ventures (n.d.).

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