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The Economics of Stem Cell Research

An Interactive Qualifying Project Report

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Abstract

In 2006, Massachusetts passed the Massachusetts Life Science Initiative earmarking $1 billion for the development of the life sciences, particularly in the feild of stem cells. This IQP seeks to characterize the economic climate surrounding this initiative by looking at the actions taken by other similar initiatives taken by other states. The report will then critique the actions taken thus far and provide a set of reccommendations for future expenditures.

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Project Objectives

The goals of this Interactive Qualifying Project (IQP) were to study and analyse the economic potential of stem cell research and application, to develop an unbiased plan for the investment of the $1 billion set aside by the Massachusetts Legislature for the Massachusetts Life Sciences Initiative (MLSI) and to provide the community and general public with a road map of the current layout of stem cell research and application. Our findings indicate that stem cell research in the United States may have been hindered by restrictions placed on the funding of stem cell lines by the federal government. Consequently, the state governements have put forward money in the form of initiatives in order to attract stem cell research and industry so that the state may gain the benefits of this promising technology. The MLSI, passed in 2006, set aside $1 billion in funding for the life sciences. Part of this initiative is intended for use in stem cell research and related industry. Most research companies based solely on stem cell research are not making money and have partnered with pharmaceutical companies to continue research. Phamaceutical companies are attracted by potential products and treatements to be developed in the future. Although no specific products have been marketed, treatments, such as bone marrow transplant, which utilize the stem cells of the patient or a specific donor have been successful. Stem cell transport has been taken up by most biologic transport companies which are established both nationally and internationally. Storage, however, is a growing industry that has only begun to be explored. Massachusetts has set aside part of the MLSI to create a national stem cell bank and to create the first human embryonic stem cell (hESC) registry.

Methodology

The approach to gather information and analyze the data acquired for this report was broken up into four main areas: research, interviews, company comparisons, and state comparisons. The initial research was broken up into three main categories: science, legislation, and economics. The basic science behind stem cells was researched through journals, websites, and textbooks. Legislative background was pulled from journals, websites, and public documents. A working understanding of economics came from journals, stocks, company profiles, and financial reports. This initial background was supplemented through interviews with politicians, life science employees, and venture capitalists.

From all of this information, methods of comparing companies and states were put together. Companies were broken down into four sub-categories for easier comparison: large pharmaceuticals, small pharmaceuticals/start-up companies, research companies, and small business clusters. States were broken down into three sub-categories: legislation regarding stem cell research and restrictions, state initiatives with significant financial investments focused on the life sciences, and companies located within each state.

Glossary of Abbreviations[*]

Name	Abbreviation
Interactive Qualifying Project	IQP
Massachusetts Life Science Initiative	MLSI
Human Embryonic Stem Cells	hESCs
Embryonic Stem Cells	ES cells
Fetal Stem Cells	FSCs
Adult Stem Cells	ASCs
Umbilical Cord Stem Cells	UCSCs
National Institutes of Heatlth	NIH
Food and Drug Administration	FDA
Neural Stem Cells	NSCs
United States Patent and Trademarks Office	USPTO
Material Transfer Agreement	MTA
Wisconsin Alumni Research Foundation	WARF
New Jersey State Stem Cell Initiative	NJSCI
Updated Economic Benefits of the New Jersey Stem Cell Capital Projects and Research Bonds Act	New Jersey Report
Gross Domestic Product	GDP
New Jersey Cord Blood Bank	NJCBB
California Institute for Regenerative Medicine	CIRM
University of Wisconsin	UW
Wisconsin Technology Council	Tech Council
National Stem Cell Bank	NSCB
Medical Doctor	MD
University of Connecticut	UConn
Illinois Department of Public Health	IDPH
Illinois Regenerative Medicine Institute	IRMI
Maryland Technology Development Corporation	TEDCO
Maryland Stem Cell Research Fund	MSCRF
Innovative, Developmental, or Exploratory Activities	IDEA
Massachusetts Life Science Center	MLSC
University of Massachusetts Medical School	UMMS

[*] Items are listed in order of appearance in text.

Name	Abbreviation
Induced Pluripotent Stem Cells	iPSCs
Doctor of Philosophy	PhD
Worcester Polytechnic Institute	WPI
California State University Program for Education and Research in Biotechnology	CSUPERB
Massachusetts Institute of Technology	MIT

Chapter 1: Stem Cells

Currently, stem cell research and related treatments hold enormous promise for the curing of debilitating diseases such as spinal cord injury, Parkinson's disease, diabetes and many other cell-based illness. Stem cells are categorized based on defining characteristics and the sources from which they are obtained. Although not all types of stem cells are used in current research, it is important to first gain an overall understanding of the terminology used. Then, more detail can be given to the specific stem cells used and the research currently being done.

Characteristics of Stem Cells

Stem cells are defined by their two unique characteristics: the ability to remain undifferentiated and their level of potency. An undifferentiated cell is a cell that has not developed into a specific cell type, such as a neuron or a red blood cell, and is capable of self-renewal. Stem cells will retain their undifferentiated state in order to create more tissue based on the needs of the organ. This allows the cell to be programmed to develop into another specialized tissue or organ of the body depending on the conditions it encounters. Stem cells divide to form two cells. One is called a daughter cell and it remains a stem cell. The second proliferates and then differentiates into the type of cells needed in the surrounding environment. (Cooper, 2007) Potency refers to the level of differentiation already undergone by the initial stem cell. Depending on the potency, a stem cell could only differentiate into a single type of cell, such as muscle stem cells, which only become muscle cells, or hundreds of types of cells, such as the cell that is formed from the fertilization of an egg, which will differentiate into every cell of the organism.

There are five levels of potency: totipotent, pluripotent, multipotent, oligopotent and unipotent. Totipotent stem cells can differentiate into literally every type of cell and tissue found in the organism. These cells are only found in embryos less than five days old. Pluripotent stem cells can differentiate into almost every type of cell and tissue in the organism but are limited based on what layer of the blastocyst they are apart of. Pluripotent cells are only found in embryos five to seven days old. These cells are no longer considered totipotent because the inner cell mass, the embryoblast, cannot differentiate into cells of the placenta and the outer cell layer, the trophoblast, can only differentiate into cells of the placenta. Multipotent stem cells can differentiate into many types of cells and tissues but only those within a closely related family of cells. For example, a hematopoietic cell, a blood stem cell, can develop into several types of blood cells but cannot develop into a muscle cell or a nerve cell. Oligopotent stem cells are even more specialized so that they can only differentiate into a few types of cells, such as vascular stem cells, which only differentiate into endothelial or smooth muscle cells. Unipotent stem cells can only differentiate into one type of cell or tissue. As mentioned above, muscle stem cells are considered unipotent because they only differentiate into muscle cells. (Stem Cell Information, 2001)

These are the characteristics that make stem cells so promising. If the differentiation of the cells can be externally controlled, then the therapist can cause the cells to re-grow damaged tissues, such as muscles or nerves, that don't normally regenerate after injury or in the case of certain illnesses.

Sources of Stem Cells

Stem cells are drawn from four sources: the inner cell mass of a blastocyst, the fetal and adult body, and the umbilical cord of newborns. (International Society for Stem Cell Research, 2008)

Stem cells originating from the inner cell mass, or embryoblast, of a blastocyst are called embryonic stem cells (ES cells). The blastocyst is the fourth stage in development of the embryo usually forming four or five days after fertilization and lasting until the sixth or seventh day. The blastocyst is made up of between 100 and 150 cells divided into two layers, the trophoblast and the embryoblast. The trophoblast forms the outer layer of the blastocyst and is made up of between 80 and 120 cells. This layer will eventually form the placenta. The embryoblast, consisting of 20 to 30 cells is the primary source of ES cells. (Marieb, 2007) This is done by inserting a syringe or pipet into the blastocyst and gently siphoning out the embryoblast. ES cells can also be obtained from earlier stages of embryonic development, such as at the 8-cell stage, but as this results in many fewer cells per extraction, this is rarely done. (Cooper, 2007) (See Figure 1.1) As hinted at, the extraction of ES cells from the blastocyst terminates further development. The advantages and disadvantages of ES cells from a research perspective will be gone over in more detail in the *Current Areas of Research* and *Ethics* sections as well as later in this section.

Undifferentiated cells found throughout the body of the organism in tissues such as bone marrow and skin are called fetal stem cells and adult stem cells (FSCs and ASCs) depending on the age of the organism from which they are extracted. (International Society for Stem Cell Re-

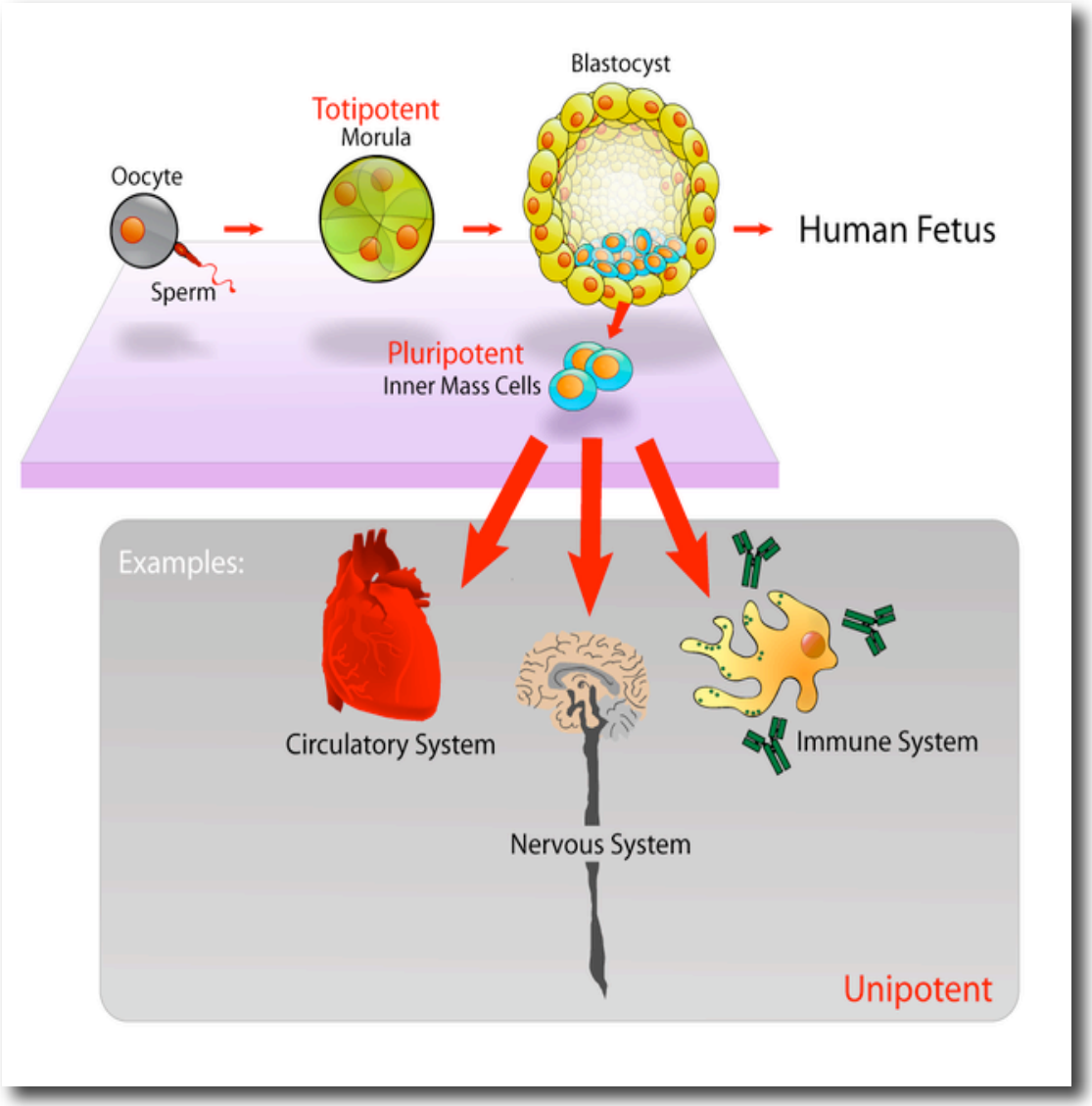

Figure 1.1: A diagram showing the progression of cells from a totipotent to a unipotent state detailing the extraction of ES cells.

search, 2008) FSCs are extracted from the organs and tissues of the fetus as well as fetal cord blood, baby dental pulp, and amniotic fluid. These cells are hard to distinguish from ASCs and are not used to great extent in therapeutic research and so will not be discussed further due to their controversial source, namely aborted fetuses. However, research continues to show that there are differences that could lead to more distinct classification in the future. (Vaziri, 1994) Most fully differentiated cells in adult animals are no longer capable of dividing. Therefore, in

almost every tissue of the body, ASCs are present to maintain and repair. In this capacity, ASCs last throughout the lifetime of the organism and are essential for the continued function of almost every organ. ASCs are further classified based on the families of cells into which they develop. For example, hematopoietic stem cells give rise to all types of red blood cells, white blood cells, and platelets, whereas epidermal stem cells undergo three to six divisions, called transit amplifying, before differentiating into absorptive epithelial cells, goblet cells, and enteroendocrine cells. (Cooper, 2007) (See Figure 1.2) As ASCs are found throughout the body, they can be extracted from whichever tissue is the topic of study and are therefore more targeted to diseases or disorders that affect a specific organ or tissue. These applications will be discussed in more detail in the *Current Areas of Research* section. Advantages and disadvantages will be discussed in more detail later in this section.

Stem cells isolated from the umbilical cord blood of newborns are simply called umbilical cord stem cells (UCSCs). UCSCs are very similar to hematopoietic stem cells in that they fulfill the role of replenishing the blood cells of the umbilical cord and placenta. The use of these cells is that they are easy to extract and store providing an untainted stock from which to draw on. During the treatment of some cancers or diseases, the bone marrow is eradicated and needs to be reestablished quickly in order for the immune system to resume proper function. A stored sample

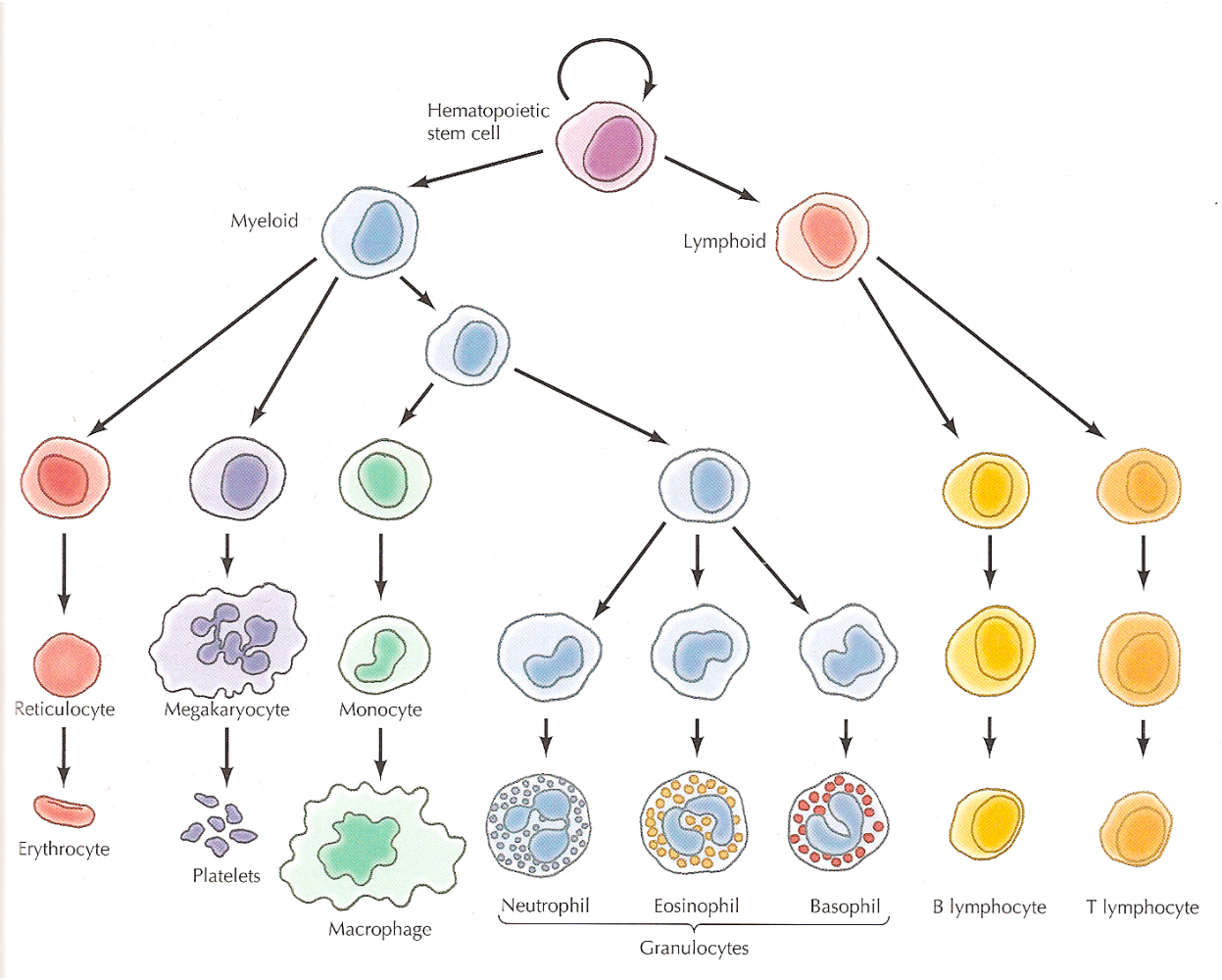

Figure 1.2: A diagram detailing the differentiation of a hematopoietic stem cell. Source: Cooper, 2007

of UCSCs from the patients umbilical cord would provide a perfect match when a donor proves hard to find. Also, stored UCSCs from an unrelated donor can be used. Very little further research is being done with these cells but they will be discussed later as pertaining to stem cell storage.

Despite the diverse sources, the majority of research that is undergoing now uses embryonic and adult stem cells. There exist advantages and disadvantages for both embryonic and adult stem cells. ES cells can develop into the three types of tissues: ectoderm, mesoderm and endoderm, which can develop into all other kinds of cells in the body. Endoderm can develop into

pancreas, lungs, liver and other organs. Mesoderm can become blood, muscle and connective tissue. Ectoderm can develop into neurons, sensory nodes and others. (Marieb, 2007) ASCs are less potent than ES cells, therefore their potential application in the medical field is limited to the family of cells to which they belong. However, since ASCs are found in almost every tissue of the body, specific researches could remove this limitation. Because ES cells are only found in embryos, there are fewer viable cell lines available for research whereas ASCs, although harder to extract initially, are available in any living organism and can be isolated much more readily. However, ASCs' greatest advantage over ES cells is that they do not cause as much ethical controversy . For ES cells, the most prominent issue is that the harvesting of ES cells from fetal tissue involves the destruction of the human embryo. This issue will be discussed in much greater detail in the *Ethics* section. Because of the potency of stem cells, many physicians and researchers are striving to apply them to different treatments, including Parkinson's disease, spinal cord injury, myocardial disease, diabetes, hemophilia, sickle cell anemia and many other cell-related diseases.

Current Areas of Research

Because of the great promise of stem cells, this being that their applications could be limitless, research involving stem cells is as vast and diverse as the cells themselves. For the sake of brevity, this report will focus on six of the most promising and prominent research areas, which include: gene therapy, treatment of Parkinson's disease, correction of spinal cord injuries, treatment of diabetes, therapy of myocardial diseases, and treatment of sickle cell anemia.

Gene Therapy

Only non-embryonic human stem cells have been used in the study of cell-based gene therapy but scientists have started exploring the possibility of using hESCs in such therapies.

Gene therapy is a very recent and experimental way to treat human diseases. Compared to traditional drug therapies which administrate chemicals synthesized outside the body, gene therapy directs the patient's own cells to produce and deliver a healing agent. Genetic engineering, which is the elimination or introduction of special genes to physically alter or supplement the function of an abnormal gene by providing a copy of a normal gene, is mainly used for three purposes: (1) to directly repair a gene, (2) to provide a gene that gives new functions, or (3) to regulate the activity of other genes (Stem Cell Information, 2001).

Currently, there are about 180 gene therapy clinical trials in the US that are cell-based and 75% of these trials use human stem cells, particularly hematopoietic stem cells to deliver transgenes into patients. Transgenes are genes or genetic materials that have been transferred naturally or by any of a number of genetic engineering techniques from one organism to another. The major reason that stem cells are used in cell-based gene therapies is because of their ability to self-renew which may decrease or eliminate the need for repeated administrations of the gene therapy (Stem Cell Information, 2001).

Of all the types of stem cells, hematopoietic stem cells are most commonly used. This is because they can easily be removed from the body through the blood or adult bone marrow or the umbilical cord blood of newborns. Moreover, it is easy to identify and manipulate them in the laboratory and then return them to patients via injection. The other advantage that hematopoietic stem cells have is their ability to migrate to many different places in the human body, especially the bone marrow, the liver, and the spleen, all of which can be strategic locations for localized

delivery of therapeutic agents for disorders that are not related to the blood system such as immunodeficiency disease. (Stem Cell Information, 2001).

With the development of therapeutic medicine, more and more scientists have embraced gene therapy; however, certain groups of people still hold objections to it because of the failure that occurred in 1999. At the University of Pennsylvania's Institute of Human Gene Therapy in Philadelphia, a patient, Jesse Gelsinger, died from a reaction to gene therapy. He accepted the experimental treatment that had the potential to cure his disease. Unfortunately, the experiment failed and he was killed. After his death, the Food and Drug Administration (FDA) and NIH launched investigations of the University of Pennsylvania studies. Later the FDA quickly shut down all the clinical gene transfer trials at the University of Pennsylvania. The FDA also stopped gene therapy trials in a great number of other research institutes, started launching random inspections of 70 clinical trials, and instituted new reporting (Stem Cell Information, 2001).

Since then, the number of researches on gene therapy has largely decreased because the public has lost confidence in it.

Parkinson's disease

Parkinson's disease is a type of brain disorder. It manifest when certain neurons in the substantia nigra of the brain die or become impaired. These neurons normally produce dopamine which is a critical chemical in the brain that allows smooth and coordinated function of the body's muscles and movement. However, when approximately eight percent of those dopamine-producing cells are damaged, the symtoms of Parkinson's disease start to become evident (National Parkinson Foundation, 2007).

In the United States, Parkinson's disease is one of the most common neurodegenerative disorders that affect at least 500,000 people (National Institute of Neurological Disorders, 2006). Moreover, about 50,000 people are diagnosed as Parkinson's disease annually. Therefore, each year a huge amount of money is invested in the related research to find out a cure for it. For various reasons, traditional treatments that focused on surgical therapy and medication failed to effectively treat this disease (National Parkinson Foundation, 2007).

Stem cells offer hope to provide a potential treatment for Parkinson's disease. Researchers have been exploring the effective way to transplant stem cells into the target positions of the brain where dopamine is needed. They cultivate stem cells from bone marrow and program them to be similar to those dopamine-producing neurons. Because Parkinson's Disease is caused by the dysfunction of dopamine-producing neurons in the thalamus and nothing else, it is one of the most likely beneficiaries of stem cell research (Borthwick, 2008).

Spinal cord injury

There are over 11,000 Americans who suffer from spinal cord injury annually, mostly from traffic accidents. Spinal cord injuries cause the loss of ability to regenerate myelin, which is a layer that insulates nerve fibers that transmit signals from the brain, resulting in paralysis. The effects can be permanent since myelin cells are not able to regenerate on their own. (Society for Neuroscience, 2004)

Recently, Hans Keirstead and his coworkers in Reeve-Irvine Research Center used a human ES stem cell treatment to successfully restore the insulating layer for neurons in rats after they had been injured for seven days. The restored functions include the recovery of certain motor skills. However, the same treatment failed to treat rats with the same injury but with a longer

time span for about ten months. This research suggested that neural stem cells (NSCs) bring hope in the treatment for spinal cord injuries, but most possibly only be effective for a certain period of time after the injury.

Diabetes

Diabetes is a disease in which the body fails to produce or properly use insulin, a hormone that is essential to convert starches, sugar and other types of carbohydrates into energy essential for the human body. Currently in the United States, about 7.8% of the population is suffering from diabetes (American Diabetes Association, 2009).

There are two types of diabetes: in type I diabetes, the patients' bodies fail to produce insulin and this lack of production generally results from the autoimmune destruction of pancreatic β-cells. If patients cannot receive treatment, they can suffer from a large number of other diseases, including nerve damage, kidney damage, heart disease etc. Currently, most of the patients rely on daily injection of insulin to maintain its level in their body or use organ transplant which is the best way to cure it. However, the pancreas allograft transplantation is greatly limited by the insufficient number of donations and the accompanying rejection by the host (American Diabetes Association, 2009).

A recent study done in vitro used undifferentiated hESCs to demonstrate their differentiation into pancreatic β-cells that produce insulin in human body. Stem cell treatment offers the hope of using such cell lines in cell replacement therapy for the treatment of type I diabetes in that it can differentiate into the essential pancreatic β-cells. However, isolating the pancreatic stem cells can be a very challenging task in that pancreas is a diverse organ consisting of multiple types of cells that function together(Ball, 2003).

Currently, NovoCell Inc. is a company that invested on the treatment of type I diabetes with the use of hESCs. The treatment includes the creation of insulin producing islet cells originated from human embryonic stem cells which can be transplanted into patients with type I diabetes later. The company also made success in the combination of this treatment with the cell encapsulation technique that used polyethylene glycol to cover the embryonic cell-derived islet cells and protect them from the immune system of the host. Therefore, this treatment stands out for two major advantages over other treatments for type I diabetes: no limitation on islet cell donors because of the procedure to counter immune rejection and less cell injections is required (Pollack, 2008).

Myocardial diseases

Congestive heart failure is the ineffective pumping of the heart caused by the dysfunction of heart muscle cells that are usually caused by a heart attack, hypertension, or coronary artery disease. Many researches have been focusing on the use of stem cells to replace the damaged heart cells and therefore restore the heart's function. All the recent studies have shown that stem cells have great potential to treat patients who have suffered from heart attack. Therefore, this brings great hope to future heart attack sufferers.

So far, the research using stem cells to restore damaged heart function have shown success in both rodent models and human clinical trials. At the Texas Heart Institute, fourteen dying patients with heart failure accepted stem cell treatment. Stem cells were collected from the bone marrow of those patients and then were injected back into them later. There was another group of patients that did not undergo the stem cell treatment. After about two months, compared to the

untreated group, the treated group could pump more blood and experienced less chest pain (Fischman, 2003).

Sickle cell anemia

Sickle cell anemia is the most common inherited blood disorder in the United States. It is a disease in which the body produces misshapen red blood cells that do not last as long as normal, round red blood cells and lead to anemia. The abnormal sickle cells pile up in the blood vessels, causing pain, anemia, infections, organ damage, and stroke. In the United States, there are approximately 80,000 people who have this inherited condition. There is no known cure other than stem cell transplantation at current stage. (National Heart Lung and Blood Institute, 2008).

Researchers at Memorial Sloan-Kettering Cancer Center devised a new way using stem-cell based gene therapy that genetically reverses sickle cell anemia in the human cells. In this gene therapy, a viral vector was introduced in cell cultures of patients with sickle cell anemia to prevent the production of the abnormal hemoglobin which is the cause of sickle cell anemia. The researchers found that the newly formed red blood cells produced normal hemoglobin and suppressed the production of the misshapen hemoglobin (Samakogly, 2005).

Now Sickle cell disease can be cured by transplanting healthy hematopoietic stem cells from a donor. However, there exists a problem for most patients: it is difficult to find a compatible donor. Hopefully this difficulty can be solved in the near future.

Ethics[*]

[*] For a well-thought out and detailed analysis of the ethical and moral implications of all stem cell types, please see "The Stem Cell Controversy" by Jessica Collins (02E023I)

With any type of research or treatment, there are always ethical implications to the actions taken. Stem cells, and more specifically hESCs, have formed the center of ethical controversy since their derivation in 1998. The heart of this debate is made up of several central questions. The most vehement arguments tend to stem from the moral status of the human embryo itself, and whether this status necessitates that it be protected under law. Further extrapolation from these questions brings into question the status of newly formed hES cells.

ASCs and UCSCs do not raise these same issues as they fall under the same ethical considerations as donated blood or somatic cells. FSCs raise even greater ethical controversy because of the debate surrounding abortion in general. When this is merged with stem cell controversies, it creates ethical dilemmas not worth pursuing.

Convictions designating the moral status of the human embryo tend to follow three general trends. Some people believe that human life begins at the “moment of conception”, namely the point at which a sperm comes into contact with an egg. From a biological perspective, this is a misnomer as the genome is not fully established as a diploid until at least 24 hours after the sperm and egg merge. Another belief is that a person is gradually formed throughout the development of the embryo into a fetus designating conception as merely the first stage along this development. A third group believes that, although the human embryo is representative of human life, it may be taken for the sake of saving others. These viewpoints are flexible and so some individuals will adhere to more than one but, in general, people seem to agree with at least one of these viewpoints.

Chapter 2: Economics

Since the 1970's, stem cells have been advertised as a potential panacea to treat any and all illness. Due to the cell's unlimited proliferation potential, researchers believe that stem cells can be used to treat a number of major diseases that are currently untreatable and cost the U.S. billions of dollars. Examples of such diseases include Parkinson's disease, Alzheimer's disease, diabetes, and spinal cord injuries, some of the most prevalent and expensive diseases within the United States. At present, there are no marketable stem cell products that have been released, and so the majority of stem cell companies are still in research stages. Our task is to determine whether it is beneficial to invest into these researching individuals or to take a more indirect approach and support other aspects of the life sciences field. In order to create a beneficial economic stimulus to Massachusetts, the money that is to be invested must ideally cause a return either in the form of new jobs opportunities, large tax returns, or a profit from the investment. Therefore before we delve too much into the topic at hand let us become familiarized with how the business world of today works.

Patents

In the modern world, most companies cannot survive without the use of special licensing agreements, better known as patents. Patents are specific authorities conferred by the federal governement of a country given to an individual or company granting the sole right to make, use, or sell some invention. In the United States, a patent grants a monopoly to the inventor for twenty years with the only requirements for receiving a patent being that the idea must be novel, useful, and nonobvious, and the disclosure of the invention is part of the patent application in

such a way that it enables others to replicate it. If a patent application meets these criteria, the United States Patent and Trademarks Office (USPTO) must issue a patent. The issuance of a patent does not entitle the inventor to sell or use the invention. The regulation of products and devices has always rested with relevant state agencies. (Korobkin, 2006)

In the life sciences, these patents can take varous forms. The most commonly understood form is a patent on a physical invention taking the form of a product or device designed by the inventor. Another common form is a patent conferred on a material or substance created by the inventor. A lesser understood patent type is a process patent whereby an inventor can patent the process by which a material or product is prepared. This is incredibly important with stem cells since there are very few proven methods by which stem cells can be isolated and utilized in research. The final, most abstract from is an idea patent. This is the patenting of a pre-existing device, material, or process to a new application. For instance, if a researcher decides to use the method by which you isolate mouse hematopoietic stem cells to isolate primate mesenchymal stem cells, he or she may be able to patent it. Once a company has invented a new product or idea, they are able to patent their idea in order to claim the idea and be protected by patent law. However it is important to realize that all patents are not marketable products. A company may have hundreds of patents, but only three of them might be something that is marketable and will actually make money. By holding the exclusive rights to produce and sell the marketable product through a patent allows a company to make money off of the new deliverables.

Companies

Companies can be divided into two different groups; public and private. When a company is first created it is created by an individual or group of individuals and is considered a

private company as it is run by the founder(s) and is not obligated to release information on its private operations or management to the general public. These private startup companies then typically obtain money through private investors, such as venture capitalists, in order to obtain the funds necessary to run the company. Assuming that the company is able to survive its initial hurdles, the company then has the option of entering the public market as a public company. Once a company has "gone public" then the company is able to sell stock. The larger the company, the more stock shares it will have; and the more successful the public perceives the company, the higher the worth of the stock itself. Therefore as a result the worth of a company is not necessarily determined by how much income or money that the company holds; instead, the company's total assets are reviewed and the company's worth is determined by the buying power of the public.

Investment Categories

After researching the possible avenues of investment, the number of different areas of possible investment has been narrowed down into eight different categories; large pharmaceuticals, start-up companies (which may include small start-up pharmaceutical companies, start-up research companies, or small medical device companies), small business clusters, transportation, storage, basic science, infrastructure, and private investment or venture capital. Within the provided list, stem cell research is tied to the categories of basic science, storage, and transportation. The other five categories are possible alternatives that can also be considered if it appears that investment into stem cell research is not advisable, or if the alternative strategies simply have a better projection of stimulating the economy.

The first of the alternative investment categories, large pharmaceutical companies are, as the name might suggest, large and well established companies that dabble in numerous areas of research and product development. These companies are more commonly known for their research into creating new marketable drugs, but they also have branches that create medical devices or medical instruments that are needed for medical procedures. With the large influence that these pharmaceutical companies have in the market, they are able to take advantage of the numerous branches of research and are able to have large net incomes from the product sales. Baxter International Inc and Wyeth are two examples of public large pharmaceuticals. The two companies have recorded revenues of 11.26 billion and 22.4 billion dollars respectively, and both have employee counts well over 47,000.*

Investment into large pharmaceutical companies should be made in a way that would persuade the companies into creating new facilities within Massachusetts. With their arrival there would both be short term and long term returns to the state. The immediate short term gains would be an increase of employment opportunities and increased tax returns to the state from residential taxes of employees that will move into Massachusetts, labor taxes from all the new employees of the facility, and company income taxes that will be very large as the revenue will be in the millions. Unfortunately as successful and stable as large pharmaceutical companies may seem, upon closer inspection it is a surprisingly fragile existence. While it is true that a large company is able to large net incomes in the billions, it is also true that the company has very large expenses. In order for the large pharmaceutical company to produce the large number of products to sell at market, they need to pay the expenses of creating and transporting that product. Therefore should for whatever reason the company fall even just 10% in their income, it

* Financial information was taken from the most recent Nasdaq publications.

may be enough so that the company is unable to support its expenses thus starting a downward spiral of job cuts or even factory closings. Due to the large and complex management that is required for the large company to exist disturbances, like the current economy, may cause what seemed to be a stable behemoth to fall instantly.

The second alternative category to stem cell research is small start-up companies. Unlike the before mentioned large pharmaceuticals, small companies do not make large revenues, and for the most part survive by collaborations with larger companies within its own field. When started up by an individual or individuals, the most pressing problem is for the founder(s) to find a way of funding the expenses of starting and then running the company to research or create the idea that they believe can be created. In most cases the company will seek private investors, also known as venture capitalists, or seek bank loans to obtain the necessary funds, and then work to make their idea into a reality. Unfortunately the majority of these companies are unable to bring their ideas to fruition and those who fail will eventually be closed down because they cannot continue to fund their research. For members of the group able to successfully market their ideas, they face competition against the larger companies that have much larger revenues to compete against. As a result some of these start-up companies will not aim to grow and compete with the already well established large companies, but may attempt to pursue what is known as 'exit strategy'. This is an economic term defined as:

> "A plan for disposing of a business and realizing the value of the investment made in it. The development of an exit strategy involves establishing the value of the business, identifying and selecting exit options, identifying and removing obstacles, and preparing and implementing a plan. Exit options include the sale of the business, merger, flotation or public listing,

> management buy-out, franchising, family succession, ceasing to trade, or liquidation." (BNET, 2009)

Suppose that a small start-up pharmaceutical is able to find a new protein or drug that they successfully patent. It is a very long and expensive process to then take this research and obtain all the necessary FDA approval; most researchers generalize this process to take about ten to fourteen years. The start-up pharmaceutical may not have the necessary funds to complete this task, and instead the company will be more inclined, especially if they were funded by venture capitalists, to have the company make use of an exit strategy to be incorporated by a larger company. Larger pharmaceutical companies have both the resources and expertise to simply buy the smaller company and invest the money necessary to see it to market. Through this manner the smaller company is quickly able to make a large amount of money, while the larger pharmaceutical company is able to hold the exclusive rights of producing the product and bring it to market.

A third alternative to investing into stem cells is to invest into small business clusters. Small business clusters are the collaboration of a number of small businesses to work together to reach new heights in research and product development. The money invested into this category is spent supplying devices and grant money to small companies that may not have the money to afford the research materials. Also as a added bonus, the companies will work together to achieve results that will be expedited by the free exchange of research and expertise. Thus, investment in a single company results in investment into multiple companies. Also, company clusters share resources, facilities, intellectual property, and research staff. This drastically cuts down the expenses of each company and allows any investment money to be used more efficiently.

The fourth and final alternative category is infrastructure. By allocating a fixed amount of money into the expansion of roadways, sewer systems, and other utilities, such as electricity and phone lines, the state is better prepared to absorb the influx of people, buildings, and traffic utilizing its resources. Investing into infrastructure can also be considered as investing into large companies, as large companies cannot be created without necessary infrastructure to sustain it. Infrastructure also includes the building of new facilities that will help to spur on collaboration, research, and expansion. Examples include laboratory and storage facilities that will help to curb up-front costs of larger companies moving into the state and smaller companies just getting started.

Research companies, especially ES cell research companies, closely resemble small startup companies in terms of size and monetary troubles, but the method of income for research companies are very different. Pharmaceutical companies make money by creating a number of new marketable products and use patents, also known as licensing agreements, to protect their marketable products. Also pharmaceutical companies work to develop new products and accessories for well used medical procedures and research, so they already have an established consumer base where the company will be able to make money from. Stem cell research companies are in a drastically different situation. ES cell research is still mostly in its developmental stages, and so there are not many stem cell marketable products that have been released. In fact in the thirty and so years of research in the stem cell field, it was only on Jan 23, 2009 (Cell News, 2009) that the Geron Corporation was the first research company to receive FDA approval to conduct clinical trials of ES cell treatment for minor spinal cord injuries. As a result, these research companies also use patents to help support themselves, but their patents focus more on procedures, methods, and research findings that they will receive money from.

Material transfer agreements (MTA) are liscences given out by these research companies that allow others to use their material patents for a price specified by the patent holder.

A number of early research companies, such as Geron Corporation, Wisconsin Alumni Research Foundation (WARF), and John Hopkins University, hold the majority of general research patents. This is very beneficial for these established companies, but make it difficult for any new startup research companies or individual researchers to market new products. For researchers, the MTA is free but no marketable product can be derived from the research. All findings must remain academic and open to the public domain. For research companies, an initial charge, estimated around $250,000, is levied for the MTA and then annual fees are also charged for continued research. It is also important to know that these companies are unable to make a net profit. Geron Corporation is one of the earliest and more successful of the stem cell research companies, but the company itself is unable to make money (Refer to table 2.1). When viewing the 10-k financial reports from Geron, there is yet to be a year where the company has made a net profit. The general patents that Geron holds do bring in a set income, but even when supplemented with money from both private and public investors, the company is forced to

Table 2.1: Gerons expenses in Thousands of dollars

Geron	1996	1997	1998
Research and Development Expenses	14, 260	15, 139	15, 619
Net Loss	10, 687	9, 641	10, 832
Revenue from collaborative agreements	5, 235	7, 175	6, 706
Stock High	13.250	13.375	11.250
Number of Stock holders	166	424	728

spend large amounts of money on research in the hopes that they will be able to create a novel treatment that can deliver the promise that resides in stem cell research.

The last category is stem cell storage and transportation. Unfortunately transportation is a business that is already very well established by a number of different companies. Also due to the various additional fees and expenses caused by the crossing of state lines, it is very unlikely that investing into the field would bring much stimulus to the state. Stem cell storage however is a whole different story. At present there are only a handful of national cell storage companies meaning that it is still a relatively new and developing field.

Chapter 3: State Initiatives

In order to determine the economic impact of each state's legislative actions, we have to evaluate the initiatives put in place by each state and the projected economic benefits from each initiative. (See Figure 3.1) After determining the effectiveness of other states' actions, the same analysis can be done for the actions that the Commonwealth of Massachusetts has taken, namely the MLSI. The information on state laws and financial commitments for life science research was collected using government websites, business journals, speeches, and various reports analyzing the possible outcomes of the state investment in stem cell research and facilities construction. This section of the study will evaluate all state's initiatives following a chronological timeline of states passing legislature with financial components.

Human stem cells are first isolated at Wisconsin University in November 1998 and their potential to create a vast range of treatments is superimposed on their controversial method of derivation. Two years later, it was necessary for the National Institutes of Health (NIH) to issue guidelines that regulate federal funding of stem cell research during the Clinton Administration. A year later (August 2001) President George W. Bush placed a hold on federal funding for stem cell research involving destruction of embryos. NIH is responsible for tracking federal funds awarded for stem cell research that meets certain criteria:

> "The derivation process (which begins with the destruction of the embryo) was initiated prior to 9:00 P.M. EDT on August 9, 2001. The stem cells must have been derived from an embryo that was created for reproductive purposes and was no longer needed. Informed consent must have been obtained for the donation of

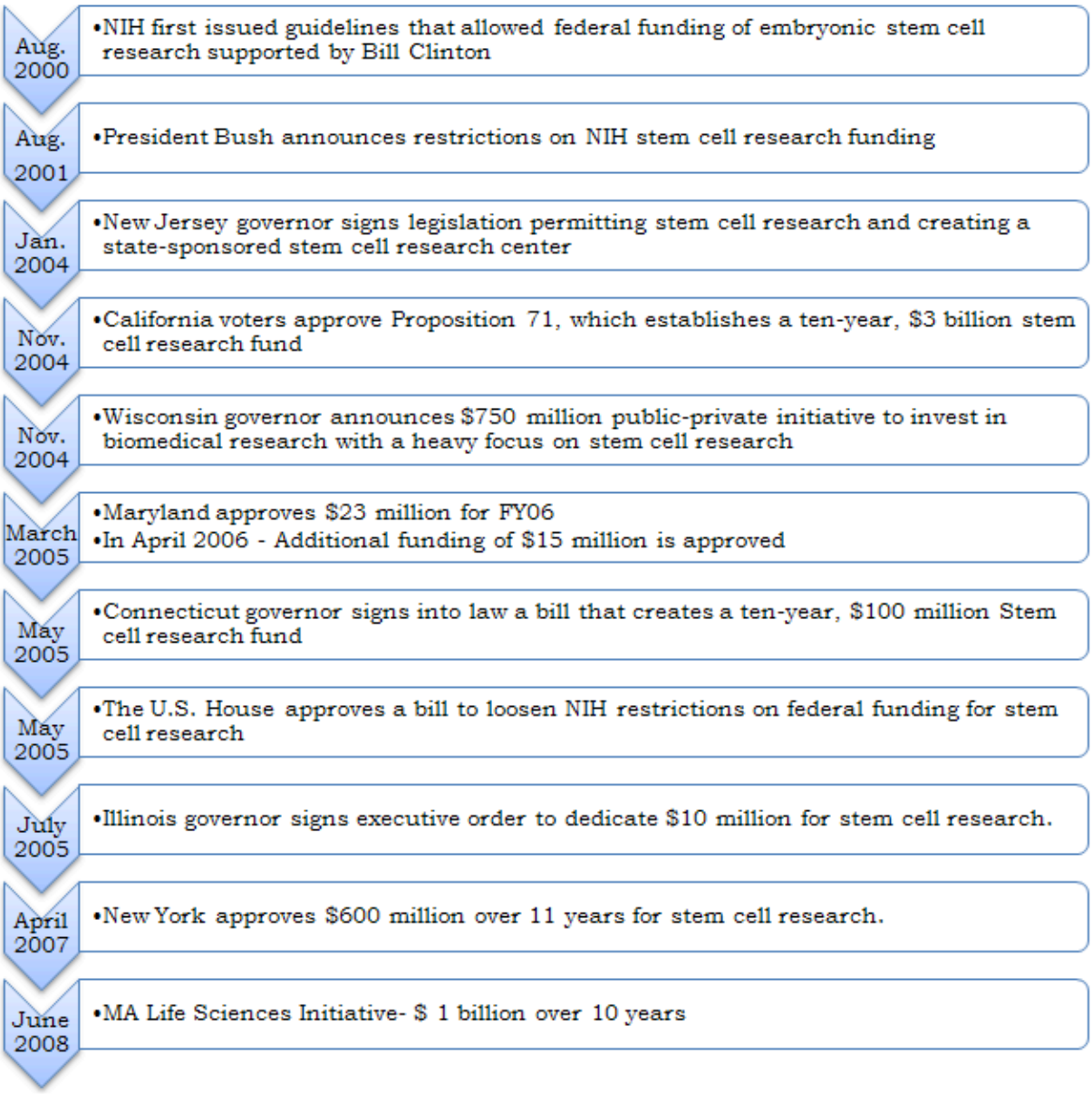

Figure 3.1: Timeline of State initiatives (Godoy, 2009)

the embryo and that donation must not have involved financial inducements." (National Institutes of Health, U.S. Department of Health and Human Services, 2009, 2009)

Some states' officials consider those federal restrictions as limiting to their state growth in educational and economic aspects. Regardless of federal policy, many state governors decide to

create funding methods for stem cell research in addition to the NIH funding. This decision is substantial for states with advanced biotechnology industries because they want to remain leaders in this area at national and international levels. Another advantage of state life science initiatives is preventing biotechnology-related companies and scientists from relocating to other states or countries overseas.

New Jersey

In 2004, New Jersey becomes the first state to finance hESC research including cell lines prohibited by the Bush Administration. The Democrat governor Corzine considered New Jersey State funding as "an important step in our growing partnership with private industry to fund this promising and potentially life-saving science." (State of New Jersey, 2004)

The New Jersey State Stem Cell Initiative (NJSCI) was revised after the first report "Economic Benefits of the New Jersey Stem Cell Research Initiative" prepared by Joseph Seneca and Will Urving at Rutgers University for Office of the Governor in Sept. – Oct. 2005. In October 2007 a new report was prepared for the New Jersey State Senate President Richard Codey by the same authors (See Table 3.1). "Updated Economic Benefits of the New Jersey Stem Cell Capital Projects and Research Bond Acts" (New Jersey Report) explains in details the revised benefits from the newly signed initiative.

The New Jersey Report outlines authorized expenditures of $270 million for construction and equipping of stem cell research and other biomedical facilities and $450 million in funds for on-going stem cell research, which means $120 million more than the infrastructure expenditures initially proposed and $220 million more than the original expenditures planned for research grants. Based on the revised calculations for projected benefits for the state generated from the

Table 3.1: Two Combined Economic Impacts on New Jersey of $270 Million in Capital Expenditures and $450 Million in Research Expenditures for Stem Cell and Other Biomedical Research Facilities (Current $) - (Seneca, 2007)

Indicator	Capital Expenditures ($270 million)	Research Expenditures ($450 million)	Total Expenditures ($720 million)
GDP	$186.5 million	$360.2 million	$546.7 million
Employment	2,681 (job-years)	5,085 (job-years)	7,766 (job-years)
Income	$ 153 million	$322.6 million	$475.3 million
State Taxes	$6.6 million	$13.1 million	$19.7 million
Local Taxes	$7.4 million	$14.4 million	$ 21.8 million

NJSCI, 7,766 job-years (one job-year is equal to one job lasting one year) will be created and they will generate a total of $475.3 million in income. An estimated $41.5 million in state and local taxes will be generated from the newly created employments. In addition to that $546.7 million in Gross Domestic Product (GDP) will be generated that would not have been possible if the initiative was not in action. (Seneca, 2007)

In 2005 the creation of an umbilical cord blood and placental stem cell bank was planned. This investment was made as a result of the NJSCI, which makes this facility the first U.S. publicly funded stem cell bank. Two years later all operations of the New Jersey Cord Blood Bank (NJCBB) were taken over by a non-profit organization called Community Blood Services. This is the only public cord blood bank for the State of NJ. (Community Blood Services, 2007)

California

California is the first state to propose state funding for stem cell research but the proposition isn't ratified until after the NJSCI. In November 2004 Californians approves Proposition 71, which states that nearly $3 billion general obligation bonds will be invested in stem cell research. The targeted institutions are universities and medical schools that are involved in stem cells programs. The funding is divided so that 90% is earmarked for research and 10% for facility creation. (See Figure 3.2 below) The total bond cost with interest is estimated to be $5.4 billion (Baker, 2004) according to the authors of the "Economic Impact Analysis" report. The analysis is based upon Proposition 71 and it estimates the financial benefits for the State of California as a result of the investment in stem cell research. The aforementioned report evaluated the initiative over 3 time periods for total length of 35 years. Years 1 to 5 will be used to finance research facilities ($300 million) and grants ($1.25 billion). Years 6 to 14 are planned for investment in research with the remaining amount from the Initiative. This is also the time when the 30-year principal period begins. The final increment of time is years 15 to 35. It is intended to pay the entire principal and interest till the end of the period since the $3 billion Stem Cell Initiative will be spent by year 14. Reference the following figure (Figure 3.2) for breakdown of the Economic Costs of Proposition 71.

The California report is focused on four potential areas, where Economic Benefits are expected to be generated for the budget of the State of California. Even though different scenarios were discussed based on the overall therapeutic success of the stem cells research, the analysts concluded that even the worst case scenario will generate more benefits for the state and the communities of California than the investment. The first two areas of interest are the benefits generated by the investment made directly from Proposition 71 and by the additional economic activity of biotechnology in California. Primarily they will generate tax revenues from newly

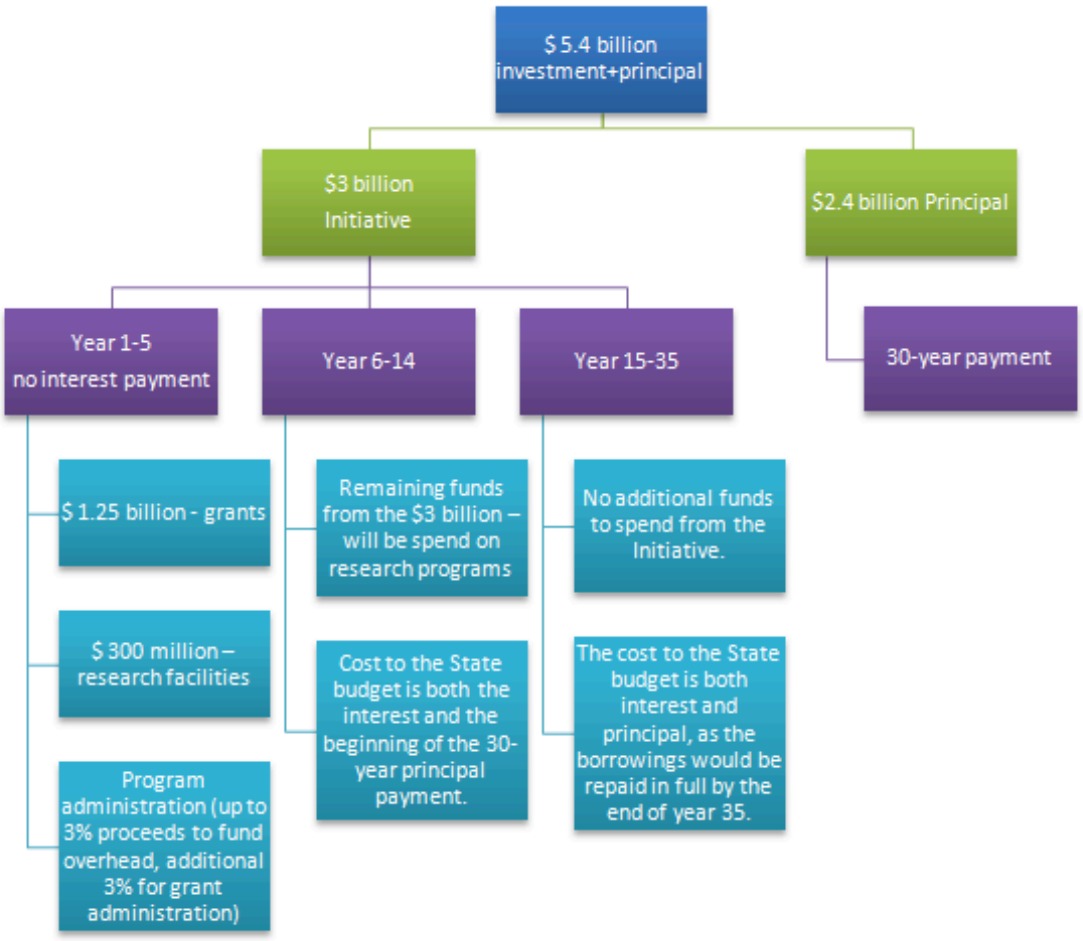

Figure 3.2: Flowchart breaking down the distribution of funds for California Initiative.

created employment that will result in increased income taxes and sales taxes. The table (Table 3.2) below lists the projected number of jobs created on average for each period of time.

The third area researched is based on healthcare cost reduction resulting from new therapies creation. Six diseases (stroke, heart attack, spinal cord injury, Parkinson's Disease, Alzheimer's disease, and insulin-dependent diabetes), which are most likely to be affected by stem cell therapeutics according to medical and scientific experts, are included in the study. The worst case scenario predicts that the stem cells research will reduce only 1% of the costs. This includes only mitigation of the 6 basic conditions or delaying the onset of some serious medical condi-

Table 3.2: Projected number of jobs created during each time period.

	Years 1 – 5	Years 6 – 14	Years 15 – 35	Total
Revenues Generated by Proposition 71 Spending	2,900 jobs/year	3,700 jobs/ year	0 jobs/year	47,000 job-years
Increased Biotechnology Investment in CA (2.5% industry augment)	2,400 jobs/year	7,500 jobs/year	11,000 jobs/year	313, 000 job-years

tions. Savings for the state from this reduction of the healthcare cost are approximated to be $3.4 billion (Baker, 2004) over the lifetime of the initiative. The table below (Table 3.3) lists the healthcare costs to Californians and to the State Budget together with each case's projected savings.

The final source of benefits for California comes from royalties that result from the Initiative funding. A moderate scenario is considered to generate royalty revenue of $500 million (Baker, 2004) over the life of grant investment in universities and Medical Centers in California.

Proposition 71 created the California Institute for Regenerative Medicine (CIRM). This agency is responsible for grants and loans that are provided for stem cell research and facilities. The grants and research awards that were granted in the past 3 years were oriented mainly towards basic stem cell research, new faculty hiring, facility equipment and tools, and new stem cell lines. The most recent grants are targeted for therapy development. Multidisciplinary teams are funded by the CIRM to transfer the most promising basic stem cell research into clinical applications and possibly create treatments. (California Institute of Regenerative Medicine, 2009)

Business expansion in California is considered to be a result of new private investment attracted to the state. The focus is on potential private start-up companies to locate in California and generate tax revenues from the employees. Income taxes will be paid by workers; sales taxes will be paid by workers and the companies that are undertaking new research. (Baker, 2004) The

Table 3.3: Healthcare costs to California and projected savings

	Case 1: Limited Therapeutic Success (1% savings)	Case 2: Increased Therapeutic Success (2% savings)	Case 3: Expanded Therapeutic Success (10% savings)
Direct Medical Cost and Lost Work Time Costs to Californians	**$ 1,316 billion**	**$ 1,316 billion**	**$ 1,316 billion**
Impact of Savings	**$11 billion**	**$ 23 billion**	**$ 114 billion**
Direct Medical, Lost Work Time, and Nursing Home Cost to State Budget	**$ 390 billion**	**$ 390 billion**	**$ 390 billion**
Impact of Savings	**$ 3.4 billion**	**$ 6.9 billion**	**$ 34.4 billion**

State initiative does not include plans for financing company creation or support certain companies with tax incentives.

Wisconsin

In November 2004, Wisconsin governor Jim Doyle announced that over the next few years the state is providing $750 million of combined public and private money for biotechnology, the majority of which will be focused on stem cell research. (Groves, 2004) The initiative includes $375 million for building a new research facility at the University of Wisconsin (UW) in Madison called Wisconsin Institute for Discovery. (Johnson, 2006) The interdisciplinary institute received private funding of $100 million for its construction in addition to the state subsidiary. WARF, a non-profit organization, provided $50 million and another $50 million was donated by John and Tashia Morgridge. (Twohey, 2006) The state earmarked $105 million for investment in research and education activities related to regenerative medicine, molecular medicine, neuroscience and cancer research at the UW Medical School and the Medical College of Wisconsin for stem cells. (Johnson, 2006) Finally, the Wisconsin state initiative will spend $134 million for ba-

sic science research and the rest of the money is planned for specific research fields such as stem cell related research.

The projected jobs that will be created as a result of the initiative is estimated to be 27, 000 according to the Wisconsin Technology Council (Tech Council). (Barba, 2006) The Tech Council was created in 2001 as an independent, non-profit science and technology advising institution to the Governor and the Legislature of Wisconsin. It has members from various levels of education, research institutions, technology companies, venture capital firms, government representatives. (Wisconsin Technology Council, 2009)

In November 2005 Governor Doyle vetoed the bill prohibiting therapeutic and reproductive cloning. His reasoning was related to the fact that Wisconsin has a leading role in stem cells research. In a speech the governor said:

> "the bill would criminalize some of the most promising scientific techniques used by stem cell researchers, not only potentially delaying cures to some of humanity's oldest and deadliest diseases but also costing Wisconsin jobs in the future." (Doyle, 2005)

The Wisconsin Life Science Initiative was created in response to the California Initiative because UW is considered to be the birthplace of stem cell research since it is the first place where hESCs were isolated. Governor Jim Doyle emphasized that this state initiative will build on the state money, "nearly $1 billion"(Ertelt, 2004), that was spent over the last decade on medical research facilities. He also said that:

> "Other states, like California, are trying to play catch-up and build from scratch what we already have… Wisconsin can't match California dollar for dollar, but California can't match what Wisconsin already has, including the

> best scientists in the world and first-class research institutions" (Ertelt, 2004)

UW Madison is primarily funded by WARF, which also holds patents for many stem cell lines discovered at the University. It also hosts the WiCell Research Institute, which is a private, non-profit supporting organization to the UW using private and federal funding to invest into stem cell research. These conditions make Wisconsin the most appropriate location for establishment of a stem cell bank that will be able to store and distribute stem cell lines to researchers. In 2005 the first National Stem Cell Bank (NSCB) is created at the WiCell Institute by NIH. The six approved providers of stem cell lines (in the US: WiCell at UW-Madison, University of California -- San Francisco, and Novocell; international: ES Cell International in Singapore; Technion in Israel; and Cellartis in Sweden) are allowed to deposit only the 21 stem cell lines included in the NIH hESC Registry.

All stem cell lines have to pass a complete quality control process before distributing them to scientists. The testing process begins upon receipt of a new cell line and its purpose is to verify the line's identity, characteristics and purity (lack of contaminants). Currently only 16 cell lines have completed the quality control and are available for research. (Kelly, 2009)

Connecticut

Connecticut also approved state funding for stem cells research in January 2005. Governor Jody Rell decided to provide funds from the state's budget surplus of $315 million (in 2005). In a speech Governor Rell said:

> “This fund is a catalyst, intended to attract other investments and generate opportunities for growth… It makes obvious sense from an economic

> standpoint as well as a medical and scientific view. The growth of the bio-science industry in Connecticut has been critical to our state's economy, with pharmaceutical and biotech companies employing some 18,000 people. We intend to build on that leadership role." (Rell, 2005)

Her initial proposal was for $20 million over 2 years, but Yale School of Medicine Dean Robert Alpern, MD, suggested that long-term commitment for research funding is required in order to keep the state of Connecticut competitive among the states which already have legislature passed. (Przymusinski, 2005) A scientific breakthrough was a turning point in the governor's decision to sign the legislation, which provides $ 100 million for human embryonic stem cell research over 10 years. (Silverman, 2005)

In March 2005 the University of Connecticut (UConn) at Storrs announced their successful creation of embryonic stem cells from cloned cattle embryos. The Chinese scientist Xiangzhong "Jerry" Yang that UConn was collaborating with was invited to lead the research activities at the National Center for Stem Cell Research in Beijing. He was determined to leave Connecticut if no state funding was provided for the research at UConn. (Hathaway, 2005)

The Stem Cell Research Advisory Committee was created as a control institution responsible for approving specific guidelines for scientists applying for grants, and it also overlooks the funds that are spent. According to their schedule the grants have been awarded starting in September 2006. State funding was allowed not only for research but also for facility construction activities. In order to comply with the Bush Administration requirements, federal funds have to be spent solely for stem cell lines included in the NIH Registry. This means that any stem cell research not related to those lines needs newly created facilities in order to be conducted. (Hathaway, 2006)

Illinois

Illinois Governor Rod R. Blagojevich and Comptroller (financial supervisor) Dan Haynes announced in July 2005 that the state will provide financial support the to stem cell research activities, which makes Illinois the first state in the Midwest to commit public money for stem cell research. In a speech Governor Blagojevich said:

> "Since the federal government has chosen to stall the medical advancements that will come with stem cell research, it is up to the states to take action… We cannot allow our citizens to suffer when relief may be available… Stem cell research is a largely untapped medical resource that may lead to cures for painful diseases ranging from cancer to Parkinson's. We owe it to people who are suffering to exhaust every possibility to better treat or perhaps even cure disease."

On the other hand, comptroller Hynes said:

> "Today, the state of Illinois made a down-payment on hope for the millions of Illinoisans or their family members who are suffering from devastating diseases or injuries. This is not hope clung tenuously to wishful thinking, but realistic hope, grounded in scientific advancements already made and strong consensus within the scientific community that stem cell research holds limitless potential… " (Blagojevich, 2005)
>
> "In the world of medical research, the fight for cures is waged one grant at a time. Today, I am proud to say we've given our scientists ten million more weapons to win that fight. In so doing, we are also giving hope to the mil-

> lions of Americans who suffer from debilitating diseases that stem cell research has the potential to defeat." (Illinois Regenerative Medicine Institute, 2006)

The governor signed an executive order authorizing $10 million in grants for adult, cord blood and embryonic stem cell research. The money was directed to the Illinois Department of Public Health (IDPH) to create a program to award grants for development of treatment and cures involving stem cells. The initiative created the Illinois Regenerative Medicine Institute (IRMI). The IRMI program is responsible for issuing grants, and to establish appropriate requirements and regulations complying with the Executive Order of Governor Blagojevich. It states that research involving human cloning is unlawful and no funding will be provided. The same rule applies for trading with embryonic or fetal tissue for research purposes. IRMI also has to set up time limits concerning extraction of embryonic stem cells from blastocysts.

An independent review board was created by IDPH. It consists of eight members -- two experts in bioethics and six medical professionals from Ireland and from the US excluding Illinois. The purpose of this panel is to overlook the grant award process and make an independent review of the grant applications.

Maryland

Maryland had one unsuccessful attempt to provide state funding for human embryonic stem cell research. A bill stating that $23 million per year will be provided, including therapeutic cloning was approved in March 2005 by the Maryland House. Unfortunately, the same bill was vetoed in April 2005 on the last day of the Senate legislative session. (Nitkin, 2005) Governor

Robert L. Ehrlich made another attempt by proposing $20 million state funding in January 2006. (Wagner, 2006)

In March 2006, a bill approving $15 million over a year passed and Governor Ehrlich signed the legislation in April 2006. (Skalka, 2006) This initiative is also called the Maryland Stem Cell Research Act of 2006. During the legislative session in 2006 was established the Maryland Stem Cell Research Commission as an independent unit within the Maryland Technology Development Corporation (TEDCO). It was created to develop certain criteria and requirements for stem cell funding that will comply with the Maryland Stem Cell Research Act of 2006.

The Commission set up the Maryland Stem Cell Research Fund (MSCRF), which is responsible for promoting state-funded stem cell research through grants given to public and private institutions or researchers. The goals of MSCRF are to advance stem cell research and potentially develop clinical applications and treatments for many diseases.

The state budget earmarked $23 million for FY 2008 for the Maryland Stem Cell Research Commission that will be allocated to stem cell grants. (Medical News Today, 2008) Up to date more than $36 million was spent on financing 82 grants for stem cells research in the first two years of the Maryland initiative. For FY 2009, $18 million is allocated, which is the third year of state funding for stem cell research. (Maryland Stem Cell Research Fund, 2009)

New York

New York is one of the last states to approve state funding for stem cells research. Prior to the New York initiative, the state is third in the country in venture capital and NIH funding. It also has 32 academic biomedical institutions, 100 teaching hospitals and very well developed biotechnology and pharmaceutical industry. Considering that many states already allocated large

amounts of money particularly for stem cells research, a failure to act in time would risk the leadership that the state already has in this research area. (Barba, 2006)

In 2007 the State of New York passed legislation under the leadership of Lieutenant Governor David Paterson. The initiative is decided to be $600 million over 11 years. The first state funding of $100 million was earmarked for FY 2007-2008. The remaining $500 million is allocated for 10 years ($ 50 million per year). (Patterson 2008)

The 2007-2008 State Budget created the Empire State Stem Cell Trust and the Empire State Stem Cell Board. The Board's role is to provide grants for research that is related to the development of stem cell biology and medicine. The Empire State Stem Cell Board consists of two committees: The Funding Committee (13 members) and Ethics Committee (13 members). The Funding committee has to make awards based upon the recommendations of an independent scientific review, whereas the Ethics Committee has to make recommendations concerning scientific, medical, and ethical standards. The first round of grants totaling $14.5 million is awarded at the beginning of 2008. (Patterson, 2008) According to the Board, human reproductive cloning is not allowed and no grants will be provided.

The Institutional Development Grants are intended to increase the capacity of New York institutions and establish the appropriate conditions for stem cells research to ensure efficiency and quality of the research. Another track of funding is focused on encouraging investigator-related research and Innovative, Developmental or Exploratory Activities (IDEA) in Stem Cell Research. There are also Consortia Planning Grants that are encouraging establishment of collaboration between New York State stem cell institutions and out of the state researchers and companies. A specific grant is targeted to support the development of pluripotent stem cell derivation

Figure 3.3: Distribution of State Funds for New York

and developing potential therapeutic applications. All of these grants are summarized in Figure 3.3 above.

Chapter 4: Focus on Massachusetts

Massachusetts Life Science Center

The Massachusetts legislature created a quasi-public agency called the Massachusetts Life Sciences Center (MLSC) in June 2006. (Massachusetts Life Sciences Center, 2006) It was created to support the life sciences in the Commonwealth by investigating potential areas for investment in public and private institutions that contribute to the research and development in the state. As the state Life Science Initiative was signed off the MLSC was assigned a key role in controlling investments. By managing the $1 billion state funding the MLSC is targeting in strengthening state's leadership in the life sciences field. The major means to achieve that goal is to collaborate industry with academia, and medical research centers.

Massachusetts Life Science Initiative (MLSI)

Massachusetts is the last state to pass state initiative for Stem Cell research. On June 16, 2008, Governor Deval Patrick signed the "Act Providing for the Investment in and Expansion of the Life Sciences Industry in the Commonwealth". The legislation represents a 10-year plan to invest $1 billion in stem cell research. This package consists of $500 million of bond funding earmarked for the Massachusetts Life Sciences Investment Fund, $250 million for the research grants, and $250 million for state tax incentives. (McDermott Will & Emery, 2008)

Massachusetts Stem Cell Bank

The MLSC made investment of $8.2 million for building the Massachusetts Human Stem Cell Bank located at the University of Massachusetts Medical School (UMMS) campus in Shrewsbury, MA. The decision was made in October 2007 (Shelton, 2007) and it served as a kick-start for the state initiative. The facility is placed in the University of Massachusetts Medical School (UMMS) and it is intended to store any type of stem cell lines no matter if they have been derived before or after President George Bush's stem cell ban. The building has separate labs for NIH funded stem cells, and for non-NIH cell lines. The equipment and functionality of the labs is identical. The only reason that the separation was required is based upon the fact that the Stem Cell Bank was founded during the Bush Administration when the federal funding for stem cell research was limited to lines derived before 2001. (Borowski, 2009) The intense research using stem cells that is taking place at universities near UMMS will benefit from the Stem Cell bank because this is a way for scientists to obtain the stem cells of interest for a short period of time. The Bank will be accepting cell lines to be deposited from various worldwide locations. Currently, it provides well maintained hESC lines and induced pluripotent stem (iPS) cell lines. They are professionally cultured and shipped to the researcher. At this point this service is provided free of charge. The facility also has Education and Training division that has a goal to involve K-12 programs and the community in technical training and education programs.

International Stem Cell Registry

Another project that the MLSC funded with $570, 000 was the International Human Stem Cell Registry at UMMS. Its purpose is to create a database with all information that researcher might need concerning specific type of cell line. The registry was launched in September 2008

and it includes catalog of references to published and unpublished journals and research papers related to each hESC line. In one of his speeches Governor Patrick said:

> "The International Stem Cell Registry will provide important information for stem cell research that will lead to cures for illnesses, a stronger economy and good jobs at good wages in every region of the Commonwealth." (Shelton, 2008)

The database information is organized at different levels of difficulty depending upon the interests of the readers. For example, researchers can reference the website when writing research papers; whereas, patients could access the database in order to inform themselves. The benefit for doctors would be the opportunity to stay informed with the newly discovered therapies and advancements in medicine resulting from stem cells research. The Stem Cell Registry is constantly updated and will provide the latest information in this field. Currently, this database is the only one in the world.

Universities

Massachusetts has great intellectual potential in that it houses some of the world's most well-known universities. Higher education provides highly skilled people who create the workforce of the state industry. Universities generate a great deal of intellectual property though research and development programs. Currently, the State of Massachusetts has certain drawbacks in technology transfer, especially in commercialization of products and devices developed in those institutions. This valuable asset that the state has needs to be utilized and turned into economic benefit. There is a study called the "Growing Talent Initiative" that was initiated before the MLSI. Its purpose was to identify business needs and to work with government, higher

education, industry, and training organizations in order to establish collaboration between the aforementioned institutions. Studying industry needs and matching those needs with the academic development of the population starting from early stage education, such as K-12, and finishing with higher education, such as Bachelor's, Master's Degree and even PhD programs, is of great importance for the quality of the state workforce. Universities and academic medical centers are the teaching facilities that are responsible for providing a well-prepared workforce to enter the business market and become employees that will contribute to the general development of the life sciences. As a result these employees will be generating revenue for the companies that they work for and also their income will be generating state taxes and income taxes.

Grants

Half of the state initiative ($500 million) is earmarked for the Life Sciences Investment Fund. It is controlled by the MLSC and is planned particularly for research grants and loans. This investment is targeted primarily for higher education, training programs, and facilities construction. The funding will be provided to qualified life sciences projects or "certified life sciences companies."

Massachusetts is #1 in the national ranking list of NIH funding per capita. As shown in the figure below (Figure 4.1), the state has unquestionable leadership among 9 other states that are chosen by the highest number of biotechnology employees.

In spite of the fact that federal funding is at such high levels, the funding is still insufficient for the amount of research that is being conducted in the state, especially when the NIH funding has been lower for the last 2 years. Because other states already have strong state initiatives from 2004, the state of Massachusetts is required to take action in order to prevent educated people

from leaving the state. The state initiative grants are intended to compensate for the lowered NIH funding after 2006.

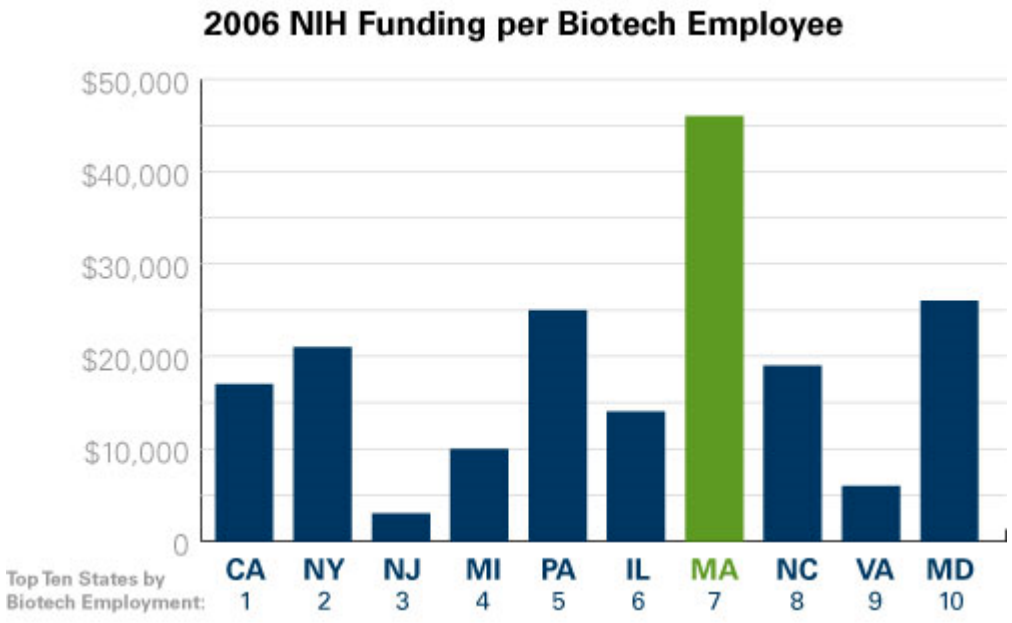

FIgure 4.1: Chart listing the top ten states in order of NIH funding totals and then showing funding per biotech employee

Small Company Investments

The State of Massachusetts has a strong educational and innovational advantage compared to other states. Combining those strengths with the long tradition of company clustering brings benefits for the organization and the community in which the clusters are located, and creates better opportunities for easy collaboration. The phenomenon of business clustering was defined by Michael Porter at the Harvard Business School. (Coleman, 2008) It is considered a business tool that helps geographically related companies that share the same area of interest to collaborate and have the advantage of sharing infrastructure, equipment, and experts in order to advance the life sciences field. The Commonwealth's life sciences Super Cluster includes various organi-

zations and institutions that work together bonded by the inspiration for innovation. The best universities, medical schools, biotechnology companies, medical device companies, and pharmaceutical companies are involved in this Super Cluster. Also venture capital and trade councils are getting involved to support the collaboration. The cluster is located in the heart of the Boston area – the Boston-Cambridge region where the Harvard and MIT are located together with many companies that contribute to the newest technologies in the biotechnology field. It is of high importance to the state and it has been growing over the past few years.

Another part of Massachusetts that has cluster seeds is the Worcester area. The main purpose for establishing it in this region is the ability to encompass higher education institutions such as Worcester Polytechnic Institute (WPI), academic medicine institutions such as UMMS, and many life science companies that are directly involved in the life sciences and are willing to collaborate with other companies or institutions.

The MLSC is working on number of programs to provide additional funding for the Cluster and support the Small Businesses throughout their struggle with commercialization of products. Early-stage companies are eligible to apply for additional financial help through the Life Sciences Accelerator Program (Massachusetts Life Sciences Center, 2008) of the MLSC. This program is intended to support selected companies with their transferring of research and development products into the market.

Tax Incentives

The MLSI provides a tax incentive program. It does not exceed $25 million per year and the budget is managed by the MLSC. The incentive is effective from January 1st, 2009 to December 31st, 2018. (McDermott Will & Emery, 2008) Companies that are eligible to apply have

to be certified as life science companies from the MLSC board. They should be working to better the understanding of human physiology and medicine and its application in therapeutics.

The certification process includes filing a Certification proposal that consists of projected revenue that the project will generate, estimated number of newly employed people, projected average salary for full-time employee, and plan for achieving that proposal. The companies have to consider both state revenue and commercial revenue. Another requirement is to have an agreement with a banking institution that would guarantee that part of the deposits will be allocated for loan payments. The company has to present any documentation justifying the project that they will be involved in. The following list highlights some of the tax incentive benefits for the certified companies:

- 10 percent Investment Tax Credit for qualifying property used exclusively within Massachusetts (refundable at 90 percent and may be carried over)
- Carryover of net operating losses for 15 years
- 100 percent credit for FDA User Fee
- Elimination of the sales throwback provision
- Extension of research and development credit to certain activities performed outside of Massachusetts (refundable at 90 percent and may be carried over)
- Qualification as a “research and development” corporation for purposes of the sales and use taxes
- Elimination of the sales tax for purchases made by certified life sciences companies for the development of their utility systems
- Deduction for qualified clinical testing expenses for orphan drugs

- Credit against excise tax for clinical trial expenses conducted in and out of Massachusetts (McDermott Will & Emery, 2008)

The certification lasts for 5 years and the companies are required to submit annual report with the MLSC to track the progress of the initially set projected benefits.

Chapter 5: Recommendations for Massachusetts

Summary

Following is a table (Table 5.1) which summarizes each area of investment that this report gives recommendations on. For the sake of brevity, the disadvantages of each category are not shown but will be discussed in later sections.

Table 5.1: Summarization of Recommendations for MLSI

Recommendation Area	Returns	Recommendation Level
Basic Research	Patents and Knowledge	Moderate
Universities	Training, teaching, and research	High
Small Pharma./ Start-up Companies	Taxes, Job Creation, and Product Development	High
Small Business Clusters	Cost Efficiency and Collaboration	High
Large Pharma.	Taxes and Job Creation	Moderate
Collaborations	Coordination of Industry and Education and Improved Employee Base	High
Transportaion	Technology Transfer	Low
Storage	Support Research, Education, and Industry	High
Infrastructure	Facilitates Population Growth and Site Creation	Moderate
Tax Incentives	Long-term Establishment of In-State Companies and Attraction of Out-of-State Companies	High

Basic Research

As stated before, because there is as of yet no major marketable embryonic stem cell based products or therapies, basic science is still an area of research. In order for new therapies and products to be created, it is necessary that research is continued within the field so that a better understanding can be obtained. However, due to the fact that the broad materials and process patents, such as the Thomson patents held by WARF, and the time advantage that states such as California and Wisconsin have, basic science should be considered as a necessary but not highly recommended area of investment. Trying to invest in a new research company in Massachusetts will not be profitable because as seen with research company Geron in Table 2.1, embryonic stem cell research companies have yet to generate a positive revenue. This is largely in part that these companies have no marketable product to generate revenue, and instead rely heavily on collaborations with large business and investors in order to support the company's research expenses.

Another drawback to basic research is that although material transfers for research purposes can be utilized for little to no cost, no marketable products can be developed from such research. Therefore, any understanding gained or breakthroughs found must remain in the educational sector. Any attempt at marketing further developments of broad base patents must be done through the original patent holder rather than by the new inventor. One way to get around this is if a product is developed from research utilizing the patented material but the product itself is not dependent on the material or process already patented. Overall, not much can be expected in terms of direct investment returns, however the further development of the technology is vital in order that the promise of stem cells actually be carried to fruition. This

technology is still very much in its infancy and so there are many avanues yet to be explored that go beyond the original broad patents.

Universities

Universities and academic medical centers are the primary grant recipient in any of the State Stem Cell Initiatives. Because these institutions play an important role in stem cells research, they are used as teaching facilities to better train people to make them more suitable for future employment. Massachusetts has historic traditions in the higher educational success. One of the most common returns from investment in universities and medical schools is patents. Intellectual property has a high potential for economic benefit for the state not only because of the licensing fees, but also because of the possible commercialization of the patented products. The figure below (Figure 5.1) shows a comparison of patents issued per state and per 100,000 people for the year of 2006, most of which provided funding for stem cells. MA has leading

Table 6. Life sciences patents issued per 100,000 people

State	Life sciences patents	Life sciences patents per 100,000 people
Massachusetts	999	15.53
New Jersey	735	8.48
California	3,028	8.35
Maryland	417	7.44
Pennsylvania	621	5.01
North Carolina	284	3.20
New York	597	3.10
US Total	6,681	2.24

Source: Patent and Trademark Office, 2006

Figure 5.1: Table showing patents issued by state and per 100,000 people

position in the list, which creates potential for future business creation if the state focuses its attention and sponsorship on technology transfer and manufacturing. By focusing on technology

transfer, better communication, and collaboration between academia and business, the Commonwealth of Massachusetts would be able to generate large profits as long term returns on investments in grants and infrastructure. The Universities in Massachusetts already have an advantage in that they can receive stem cells and information about any stem cell line. The creation of the Stem Cell bank and the International Registry is of great convenience.

As it was mentioned in the background research of the paper, Massachusetts is a national leader in NIH funding per capita. Another ranking was conducted so that only states that provide funding for stem cells were included in a comparison chart showing how much funding each state provides per capita based on the Employed Population only*. The graph below (Figure 5.2) clearly shows that Massachusetts has the advantage in State Initiative Investment over its peers. Taking into account the aforementioned leadership position of Massachusetts in terms of funding per capita, it can be concluded that the state would be able to attract researchers and new faculty into the area due to the high levels of funding available. Another conclusion can be made about university grants. Given that the research grants are intended mostly for higher education institutions, the figure below (Figure 5.3) shows the ranking of Massachusetts with the rest of the states that have State Initiative for Stem Cells Funding. The calculation is based upon the number of people enrolled in College and Graduate School. The result of that comparison reveals that MA ranks second only to Wisconsin. Considering that data, it would be beneficial for Massachusetts to invest in higher education and to provide grants for research work that goes beyond basic research. This is the method to attract people willing to pursue higher education in the life sciences. The state will be much more capable to finance programs that will support college level students and develop further their skills by preparing them for either future research

* Employed population data were obtained from the US Census Bureau. For computation purposes only, Employed Civilian Labor Force data from 2000 Census were considered

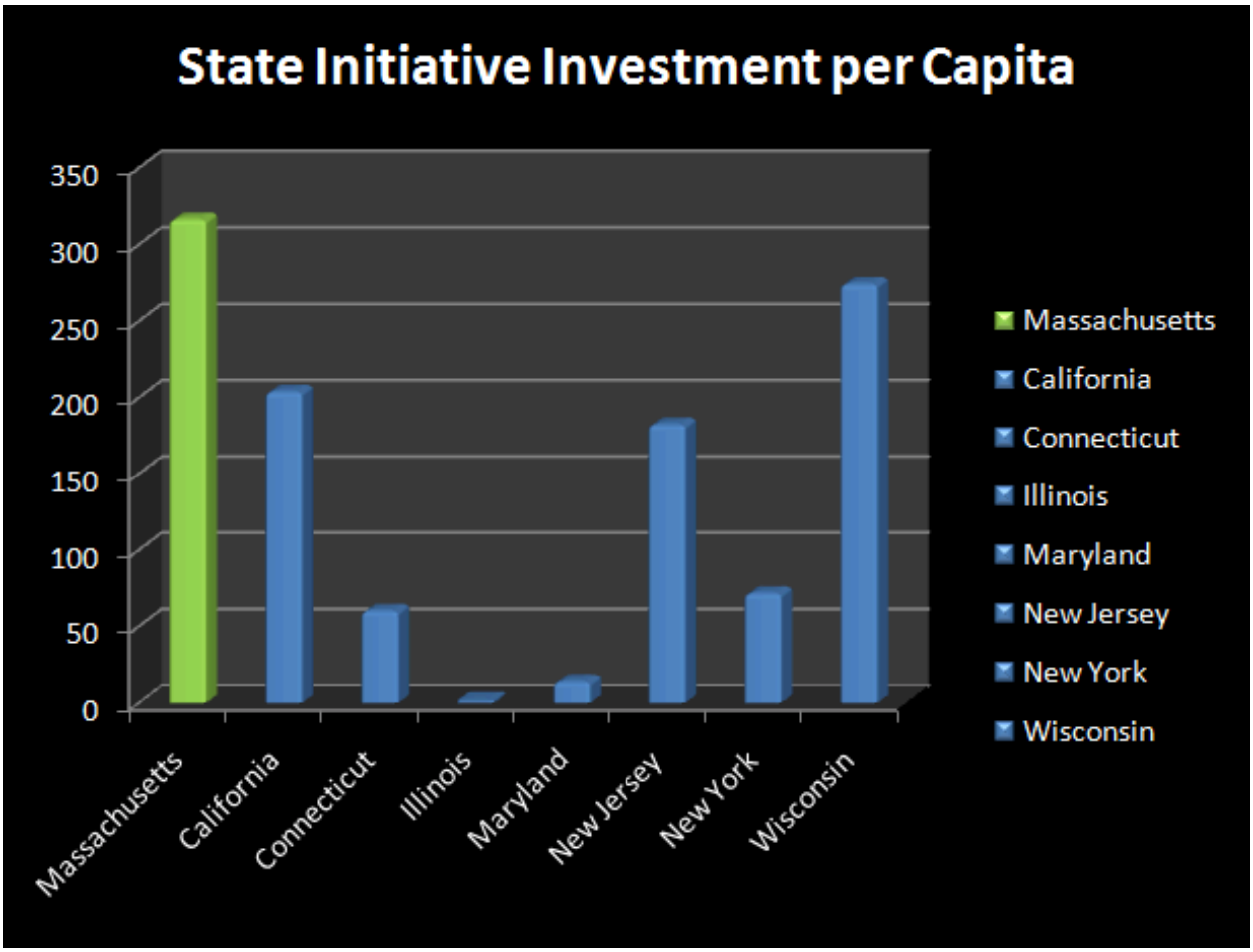

Figure 5.2: Chart showing state initiative spending per capita

work or by creating the base of a highly educated workforce that would be beneficial for both the industry and the Commonwealth.

Small Pharmaceutical and Start-up Companies

Small pharmaceutical and small start-up companies are both highly recommended for investment because of the potential that they posses. Potential is the keyword to remember when investing because, as a whole, the majority of these small pharmaceuticals and start-up companies will fail and disappear. However, it is the small percentage which are able to succeed through whom the returns will be made. While large companies are able to create huge revenues,

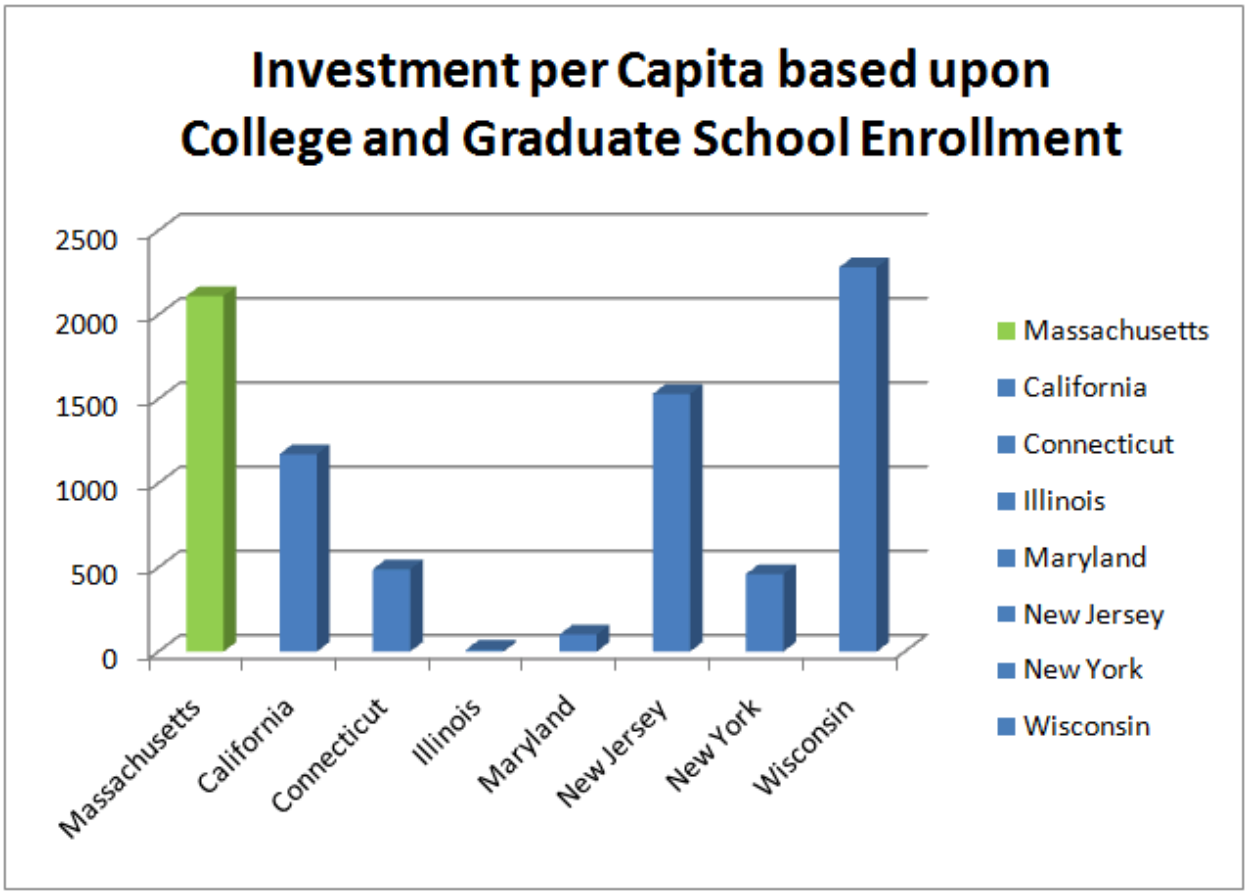

Figure 5.3: Chart showing investment per capita enrolled in higher education

their production costs are also huge. On the other hand, a small start-up or pharmaceutical company is able to run and thrive on significantly less amounts of money. As a result, investing small portions into a number of small start-ups and pharmaceuticals is prudent. The small percentage that succeed will return back the initial investment in one of following two ways: either the company will seek out an exit strategy and sell itself to a larger pharmaceutical company and thus return a percentage of that money returns to the state, or in very rare circumstances, the company will grow into a large and thriving company giving the same returns as those of a large company but for significantly less cost. Therefore, it is highly recommended that a portion of the 1 billion dollars be invested into a number of small start-up and pharmaceutical companies.

Small Business Clusters

Small business clusters are another important area of investment because it gives an opportunity to small business to work together in order to expedite research by bringing specialties of different companies together. Small companies that are unable to afford the high end machines that may be necessary for research are provided for with the money invested into this category, and it allows a collaboration between the companies to work together to find new research and come up with products. This is a highly recommended investment it gives the opportunity of minds to work together in order to take research of the field into new stages of understanding.

Large Pharmaceuticals

The appeal of investing into large companies is that if a new branch is set up it will result in a number of benefits for the economy of Massachusetts. Having a branch of a major company means that it is supported by a large money making corporation and also that the company will be able to make money soon after starting its operations. With money making operations starting so quickly, income taxes will be able to start returning the initial investment. For instance, if Baxter International were able to make a revenue of $11, 263 million*, then an income tax of 9.5%† will create a return of approximately $1, 069 million to Massachusetts solely from the company's income. Also, it will both stimulate and return investment in the form of employees. The creation of a new branch creates a number of new job opportunities, Baxter International has

* Total annual revenue for 2007.

† See *Tax Incentive* section.

20,600 employees in Illinois alone. (Baxter International Inc., 2009) With the new jobs come more income taxes and possible residential taxes if the new employees need to move into Massachusetts. Investment into these companies would be a long term investment, requiring the allocation of a certain amount of money periodically over a ten year period. However, this investment is something that is not recommended because large pharmaceutical companies make revenues that can dwarf the 1 billion dollars that Massachusetts is seeking to invest over ten years. Even a $1 billion investment is not enough to affect the larger companies, and thus should not be done. Instead if the benefits of creating a branch can be gained more prudently by investing in infrastructure to create locations condusive to the moving in of a large company. By using this in tandem with the tax incentive of the MLSI, companies are much more likely to set up branches within Massachusetts than with a direct investment.

Collaborations of academia and business

The development of Massachusetts into a leader in the life science field was cultivated by the highly educated population and the innovative workforce created from it. It is more complicated to maintain that position as the global economy becomes more competitive, particularly in the stem cell field in lieu of the federal funding restrictions put in place by the Bush Administration. Other countries began to take on leading roles within the field and this spurred some states to provide funding to continue research in this most promising field – stem cells therapy.

Massachusetts is taking action to regain its leading position by passing legislature for a $1 billion investment over 10 years. One of the biggest challenges is to coordinate industry requirements for workforce and educational centers, where the workforce is trained. The state of Massachusetts conducted a study, called Growing Talent, in the form of survey in order to deter-

mine what the industry needs are and how to establish collaboration between academia and industry. In the long run, this attempt hopes to result in a better employment base.

Taking a look at the California strategy of collaboration between academia and industry it should be noticed that the state's efforts are focused on public higher educational institutions. What is important in the example of California is that those collaborations were initiated before Proposition 71. The California Community College Biological Technologies Initiative is a statewide collaboration between biotechnology programs in the community colleges. (California Community College Biological Technologies Initiative, 2009) The California State University Program for Education and Research in Biotechnology (CSUPERB) was founded in 1987 to promote biotechnology in California. (UMass Donahue Institute, 2008) This organization serves as collaboration between the California State Universities and industry, state government and the public on issues related to biotechnology. (CSUPERB, 2009) The California Institute for Science and Innovation was created in 2000 as a result of collaboration between the state and industry. The institute is intended to "create a new environment for industry scientists to collaborate in fundamental research and to educate future scientists." (California Institute for Science and Innovation, 2008)

This strong relationship between academia, business and the state government is of great importance for Massachusetts as well. Having high intellectual and innovational potential, strong intellectual property, and various sources of funding for biotechnology gives the state high potential for financial impact on its economy. Maintaining those resources requires effective communication and collaboration between institutions. The Growing Talent study was initiated in order to determine what areas of the higher education have to be improved so that the workforce meets the industry needs. This was evaluated by conducting surveys and interviews of human resources

representatives of 100 Massachusetts-based institutions. The study included professionals from every sector of the life science industry, such as academic medical centers, biotechnology and pharmaceutical companies, medical device companies, clinical research organizations, venture capitalists, etc. (UMass Donahue Institute, 2008)

The following figure (Figure 5.4) shows the result of a survey about the difference between public and private school graduates according to employers. The common opinion is that employers consider that PhD and Master's degree recipients are well prepared after graduation. In contrast, more efforts have to be made to improve Bachelor's degree education. The action that the state has taken to support school-to-career development is the Internship Challenge program offered by the MLSC.

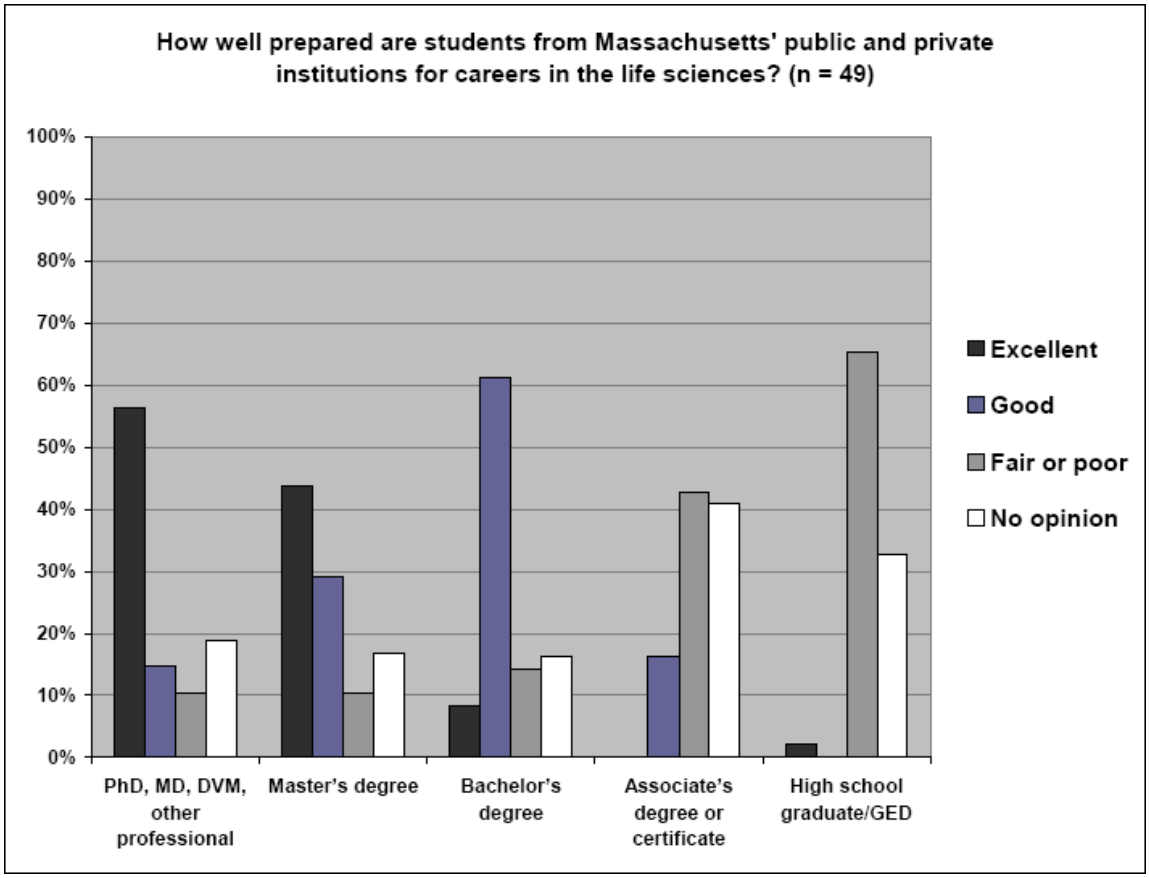

Figure 5.4: Chart showing opinion poll of preparedness of graduates of varied levels

Because Massachusetts relies heavily on international specialists for higher education positions, there is a high level of uncertainty as to the number of students that will stay in Massachusetts and generate benefits as employees. As a collaboration program the state has to increase the pipeline for residents of Massachusetts that enter higher education and also provide means for hiring more residents in the life sciences. (UMass Donahue Institute, 2008)

One of the new strategies suggested by the Growing Talent report is the improvement of technical trainings. Employers who identify an area where there is an insufficient supply of workers could partner with community colleges and send their employees for training programs in the life sciences. This is the case with Wyeth, which trained their workers at Middlesex Community College in the area of bio-manufacturing. (UMass Donahue Institute, 2008)

The figure (Figure 5.5) below makes comparison of the answers from the survey about employers' opinions about workforce coming from private 4-year colleges, public 4-year colleges, 2-year colleges, and corporate education programs. Survey respondents think that graduates from private 4-year colleges are better prepared than any other type of schooling. Their opinion is that MIT, Harvard University, Northeastern University, WPI and Boston University (UMass Donahue Institute, 2008) are the leaders within the life science education community.

Collaboration is a highly recommended area of investment by the initiative because it will reduce costs by eliminating duplication and creating more life science clusters, and it will create more economic benefits by creating a workforce better suited to meet the needs of the industry.

Transportation

Transportation was an important consideration of stem cell research as it may be important to transfer the research of one branch to another. However upon further investigation

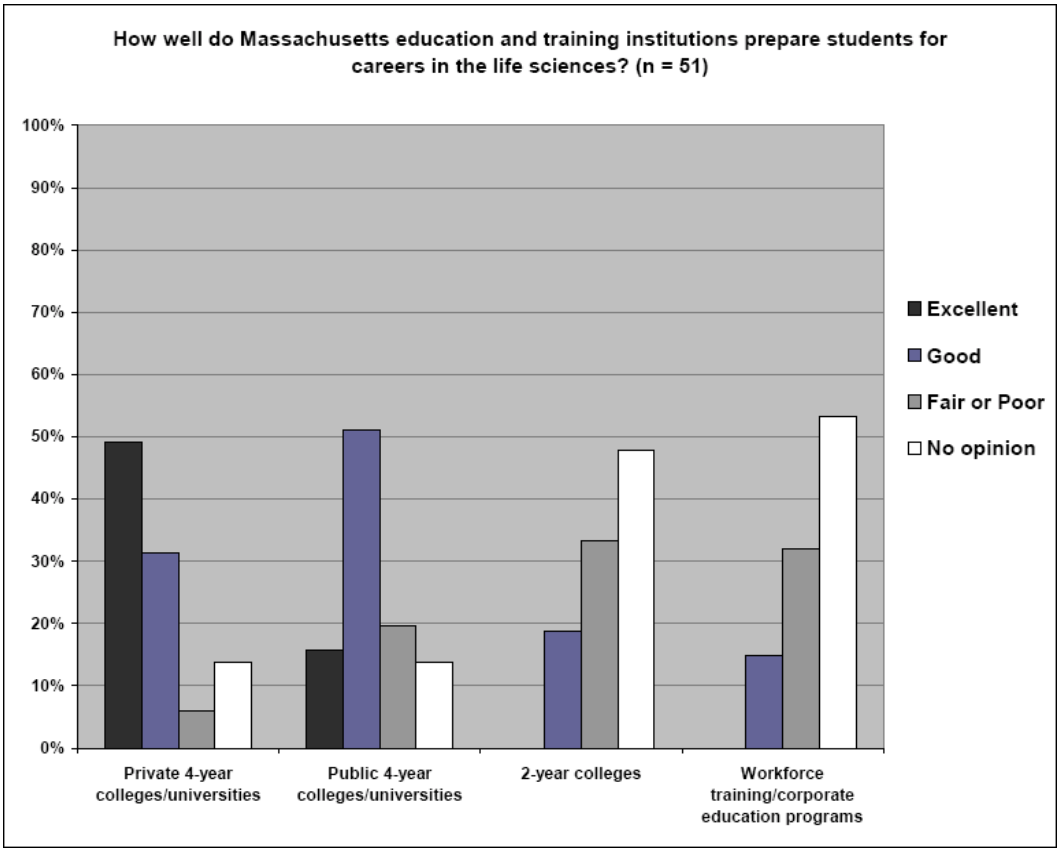

Figure 5.5: Chart showing opinion poll of preparedness of graduates for the life sciences

transportation is a tricky area of investment due to the number of state border crossing fees and the fact that there are a number of already established transportation companies that hold significant presence in the transportation industry. For material transfers on a smaller scale, the regular shipping agencies such as FedEx or UPS are able to accomodate. Their overnight delivery capabilities and hyper accurate package tracking allow for easy shipment of small frozen cell shipments anywhere in the domestic United States. For larger shipments, such as lab transfers, or overseas shipments, companies that specialize in transfering biological materials are needed. Smaller shipments that need to be preserved longer are easily handled with the packaging inovation of Minesotta Thermal Science or Cole-Parmer, which sell specially designed packaging for cryogenically preserved tissue. Companies, such as Pacific Scientific

Transport on the west coast, have the shipping and storage capabilities and specialize in lab transfers and other large-scale transfers.

Storage

Truly one of the few untouched areas, there exist only a few designated ES cell storage facilities in the world. Most stem cell banks, such as Cryo-cell International or CorCell, specialize in umbilical cord blood purification and UCSCs isolation to be set aside for when the donor may need it. Because of this specialization, these facilities fall under the jurisdiction of blood banks and so avoid the entire controversy of stem cell ethics. Prior to the grant given to set up the ES cell bank in Shrewsbury, MA, there were only two major ES cell repositories in the world. The first is the NSCB in the United States. However, since this facility recieves NIH funding, up until recently it only accepted stem cell lines permitted under the Bush administration. The other is the United Kingdom Stem Cell Bank which accepts all viable cell lines through an intensive screening process. Because there is so little activity in this field, the North American market is still very open. Also, stem cell banks are the only primarily stem cell based companies that end up making money by charging for the storage and retrieval of stem cell lines. Because Massachusetts wants to establish its stem cell bank with as many lines as possible and promote non-monetary returns such, as an open research environment and educational opportunities for all levels, the bank does not charge anything for lines being donated or lines being retrieved. The hope is that over the 10 years that the grant is in place, the Bank will become well established and be able to pay for itself once the initial investment runs dry.

Infrastructure

As stated before, in order to support the creation of new companies we first need to make sure that the infrastructure is able to support it. The first part of infrastructure is the expansion and updating of utilities and transportation flow. This might mean that sewage systems need expanding, highway roads expansion, parking lot creation, etc. Although this infrastructure does not bring profit in a short term, it is an essential part in the process of stem cell research in that it lays a good foundation for the ongoing growth in the state's life science industry. The second part is the building or relevant technical structures that can offer support to develop new cures that better treat diseases, and facilitate the operation of stem cell research. For example, through the MLSI, one of the primary objectives is to create a stem cell bank and registry for the archiving and distribution of NIH approved and non-NIH approved ES cell lines. The bank and registry will provide a great resource for both the region and the nation. Infrastructure is a necessary investment, but should only be seen as a necessity, and more of an indirect investment towards other more highly recommended areas of investment.

Tax Incentives

The economic benefits calculated in other states, such as California and New Jersey suggest that the state of Massachusetts is expected to generate state and income taxes from the newly created jobs throughout the 10-year Stem Cell Initiative. Following that pattern, the short term return for the state will be generated by income taxes from the worker's income and the residential taxes from housing. From the beginning of the initiative, the MLSC has committed $42.5 million to support the life sciences. (Massachusetts Life Sciences Center, 2009) These invest-

ments attracted more than $352 million in federal and private funding. The projected benefit is that more that 950 new jobs will be created across the state due to the initiative financing.

So far, life science businesses in Massachsetts have taken active role in financing various programs. For example, the company RainDance Technologies moved its operations from Connecticut to Lexington, MA. Through the MLSC, it received a $250,000 annual grant for 3 years in partnership with the Harvard School of Engineering and Applied Sciences and Physics Dept. for development of a new fluorescent activated cell sorter. The relocation of the company will generate taxes for MA through it's 60 employees. (Linked In, 2009)

The state would be able to expect many of the corporations to generate corporate income taxes in the long run. Since one of the weaknesses of MA is the high level of Corporate Taxes it

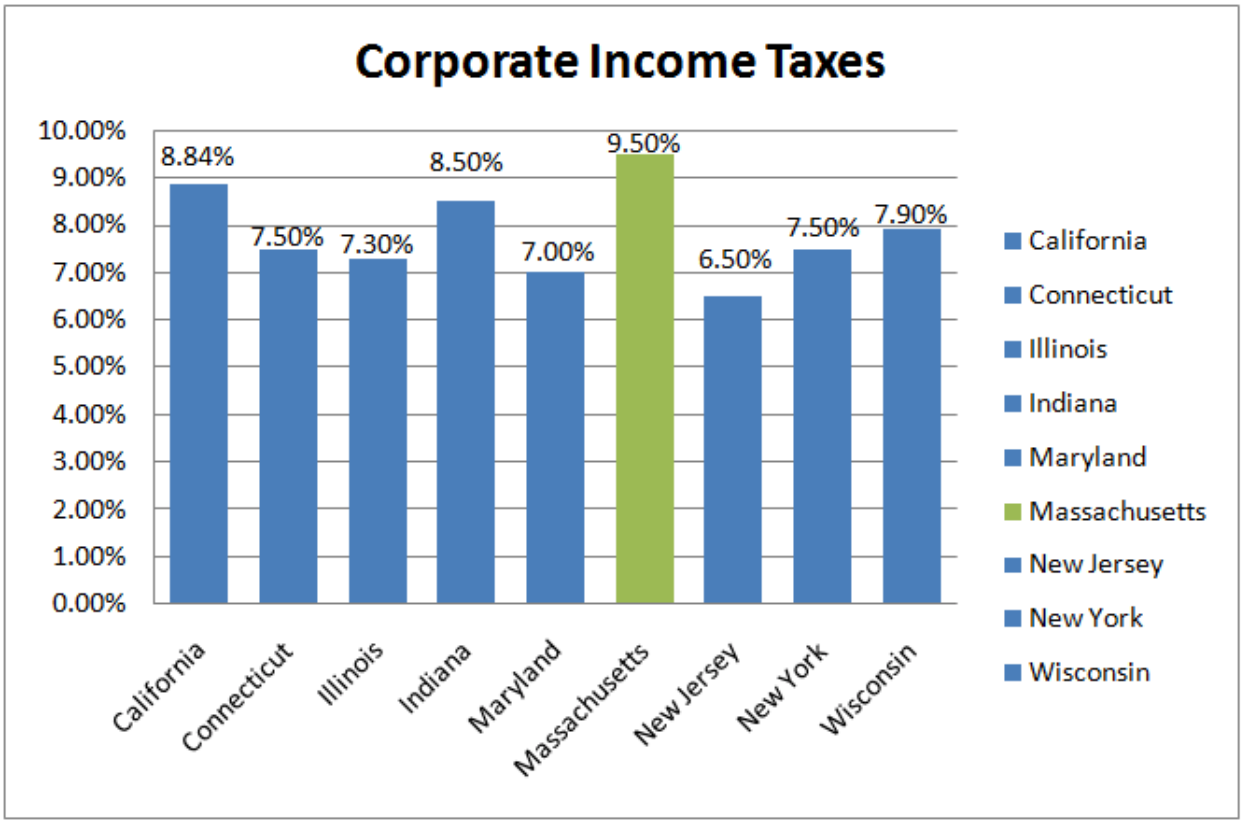

Figure 5.6: Chart showing corporate income taxes by state. Source: Governor Barbour, 2006

was necessary to create a State Tax Incentive for qualified life sciences companies. This is the method to support the small business and start-up companies in particular, and to attract big companies to locate facilities or expand in Massachusetts. In the figure (Figure 5.6) above is provided comparison of the corporate income taxes in most states that provides federal funding for stem cells research.

The high corporate income tax of Massachusetts is a disadvantage that makes the state unattractive for companies even though there are other valuable resources, such as highly educated people, the MLSI, etc. Therefore, tax incentives are highly recommended in order to counterbalance the negative stipulation acrewed since the early 1980s.

Conclusions

In general, the decisions of the MLSC have reflected the recommendations provided above. Initial funding was given to infrastructure to provide for companies moving into Massachusetts and to set up facilities such as the Massachusetts Human Stem Cell Bank and the International Stem Cell registry. Tax Incentives were also put in place for qualifying companies in order to support growing companies and bring in larger companies from outside of the state. Basic research and academia have been supported through grants. Training has been offered through UMMS via the Massachusetts Human Stem Cell Bank at both the industry and university level. Massachusetts has even sought to build a foundation for the next generation of life science employees by providing elementary through secondary level programs to interest youth in the life sciences. The decisions that Massachusetts is now making are well-suited for long-term economic and educational gains.

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Appendix A: List of Grants by State

Illinois

A complete list of researchers and institutions receiving grants is provided below:

- "$870,000 - Guillermo A. Ameer, Northwestern University for stem cell-based vascular tissue engineering to enable the development of replacement blood vessels and therefore eliminating the need to harvest existing blood vessels from the patient.
- $800,000 - George H. DeVries, University of Illinois at Chicago for stem cell therapy for recovery from ischemic stroke.
- $1,999,944 - Mary J. Hendrix, Children's Memorial Hospital for reversal of disease progression by stem cells.
- $1,990,309 - Ronald Hoffman, University of Illinois at Chicago for the Center for the Development of Stem Cell Therapies for Human Diseases to focus on the use of human embryonic stems cells and adult tissue-specific stem cells for the treatment of blood disorders, lung diseases and heart repair.
- $800,000 - Gwendolyn L. Kartje, Hines VA Hospital for human adult bone marrow-derived stem cell therapy for recovery from Ischemic stroke.
- $250,000 - Stephen J. Kaufman, University of Illinois at Urbana/Champaign for therapeutic implementation of mesoangioblast stem cells in muscular dystrophy to advance stem cell therapy for muscle and neurodegenerative disease and injury and provide a mechanism for repairing a variety of diseased tissues.

• $473,212 - Dorothy A. Sipkins, University of Chicago for mechanisms of hematopietic stem cell homing in normal and disease states with the goal of understanding the molecular signals that blood-producing cells use to travel to specific areas where these cells can survive and regenerate.

• $1,400,000 - Patrick J. Stiff, Loyola University for unlocking the clinical potential of umbilical cord blood derived stem cells to use as both blood cells as well as other tissues, including the heart muscle and nerves.

• $564,512 - Xiaozhong A. Wang, Northwestern University for genetic control of pluripotency and differentiation in embryonic stem cells to control the self-renewal and multipotency of stem cells.

• $591,322 - Matthew B. Wheeler, University of Illinois at Urbana/Champaign for mesenchymal stem cells using high-speed robot to culture, screen and differentiate stem cells as well as assess the suitability as an alternative to bone marrow as a source of adult stem cells in tissue engineered devises for the clinical reconstruction of bone and soft tissue defects using human-patient derived fat." (Blagojevich, 2005)

California

"The Independent Citizens Oversight Committee approved Comprehensive Research Grants to the following researchers **(Note: the dollar amounts shown are the four-year budgets requested by each applicant and are subject to review and revision by CIRM, prior to the issuance of grant awards)**:

Application #	Principal Investigator	Institution	Title	Amount
RC1-00100-1	Baker, Dr. Julie C	Stanford University	Functional Genomic Analysis of Chemically Defined Human Embryonic Stem Cells	$2,628,635
RC1-00104-1	Bernstein, Dr. Harold S	University of California, San Francisco	Modeling Myocardial Therapy with Human Embryonic Stem Cells	$2,229,140
RC1-00108-1	Crooks, Dr. Gay	Miriam Children's Hospital of Los Angeles	Regulated Expansion of Lympho-hematopoietic Stem and Progenitor Cells from Human Embryonic Stem Cells (hESC)	$2,551,088
RC1-00110-1	Donovan, Professor Peter	University of California, Irvine	Improved hES Cell Growth and Differentiation	$2,509,438
RC1-00111-1	Fan, Dr. Guoping	University of California, Los Angeles	Epigenetic gene regulation during the differentiation of human embryonic stem cells: Impact on neural repair	$2,516,613
RC1-00113-1	Fisher, Dr. Susan J.	University of California, San Francisco	Constructing a fate map of the human embryo	$2,532,388
RC1-00115-1	Gage, Professor Fred H.	The Salk Institute for Biological Studies	Molecular and Cellular Transitions from ES Cells to Mature Functioning Human Neurons	$2,879,210
RC1-00116-1	Goldstein, Professor Lawrence S. B.	University of California, San Diego	USING HUMAN EMBRYONIC STEM CELLS TO UNDERSTAND AND TO DEVELOP NEW THERAPIES FOR ALZHEIMER'S DISEASE	$2,512,664
RC1-00119-1	Heller, Professor Stefan	Stanford University	Generation of inner ear sensory cells from human ES cells toward a cure for deafness	$2,469,373
RC1-00123-1	Lee, Dr. Jang-Won	CHA Regenerative Medicine Institute	Establishment Of Stem Cell Lines From Somatic Cell Nuclear Transfer-Embryos in Humans	$2,556,066
RC1-00124-1	Lee, Dr. Randall James	University of California, San Francisco	Embryonic Stem Cell-Derived Therapies Targeting Cardiac Ischemic Disease	$2,524,617
RC1-00125-1	Lipton, Dr. Stuart A.	Burnham Institute for Medical Research	MEF2C-Directed Neurogenesis From Human Embryonic Stem Cells	$3,035,996
RC1-00131-1	Marsala, Dr. Martin	University of California, San Diego	Spinal ischemic paraplegia: modulation by human embryonic stem cell implant.	$2,445,716
RC1-00132-1	Mercola, Dr. Mark	Burnham Institute for Medical Research	Chemical Genetic Approach to Production of hESC-derived Cardiomyocytes	$3,036,002

RC1-00133-1	Nusse, Dr. Roel	Stanford University	Guiding the developmental program of human embryonic stem cells by isolated Wnt factors	$2,354,820
RC1-00134-1	Palmer, Professor Theo D	Stanford University	Immunology of neural stem cell fate and function	$2,501,125
RC1-00135-1	Pleasure, Dr. Samuel J.	University of California, San Francisco	Human stem cell derived oligodendrocytes for treatment of stroke and MS	$2,566,701
RC1-00137-1	Reijo Pera, Dr. Renee A.	University of California, San Francisco	Human oocyte development for genetic, pharmacological and reprogramming applications	$2,469,104
RC1-00142-1	Srivastava, Dr. Deepak	The J. David Gladstone Institutes	microRNA Regulation of Cardiomyocyte Differentiation from Human Embryonic Stem Cells	$3,164,000
RC1-00144-1	Tarantal, Professor Alice F.	University of California, Davis	Preclinical Model for Labeling, Transplant, and In Vivo Imaging of Differentiated Human Embryonic Stem Cells	$2,257,040
RC1-00148-1	Xu, Yang	University of California, San Diego	Mechanisms to maintain the self-renewal and genetic stability of human embryonic stem cells	$2,570,000
RC1-00149-1	Zack, Dr. Jerome A	University of California, Los Angeles	Human Embryonic Stem Cell Therapeutic Strategies to Target HIV Disease	$2,516,831
RC1-00151-1	Zarins, Dr. Christopher K.	Stanford University	Engineering a Cardiovascular Tissue Graft from Human Embryonic Stem Cells	$2,618,704
RC1-00345-1	Keirstead, Dr. Hans S.	University of California, Irvine	hESC-Derived Motor Neurons For the Treatment of Cervical Spinal Cord Injury	$2,396,932
RC1-00346-1	Kriegstein, Dr. Arnold R.	University of California, San Francisco	Derivation of Inhibitory Nerve Cells from Human Embryonic Stem Cells	$2,507,223
RC1-00347-1	Leavitt, Dr. Andrew D.	University of California, San Francisco	Understanding hESC-based Hematopoiesis for Therapeutic Benefit	$2,566,702
RC1-00353-1	Wallace, Professor Douglas C.	University of California, Irvine	The Dangers of Mitochondrial DNA Heteroplasmy in Stem Cells Created by Therapeutic Cloning	$2,530,000
RC1-00354-1	Weissman, Dr. Irving L	Stanford University	Prospective isolation of hESC-derived hematopoietic and cardiomyocyte stem cells	$2,636,900
RC1-00359-1	Zern, Professor Mark Allen	University of California, Davis	An in vitro and in vivo comparison among three different human	$2,504,614

(Carlson, 2007)

New Jersey

The Commission on Science and Technology received 71 complete applications for New Jersey's $5 million Stem Cell Research Grant program, including proposals from private life science companies as well as New Jersey's research universities and nonprofit institutions.

The Commission voted Dec. 16 in a public meeting to award Stem Cell Research Grants to the following:

•Treena Arinzeh Ph.D. New Jersey Institute of Technology $295,362

Nanofiber Scaffold for Stem Cell Based Cartilage Repair

To test whether stem cells can be used to repair cartilage defects with the potential for providing new tissue engineering therapies that could help cancer patients who have had tumors removed from bones, osteoporosis and other cartilage and tendon damage.

•Rick Cohen Ph.D Rutgers University $299,403

Center for Applied Training in Human Embryonic Stem Cell Biology

To provide basic and advanced training in the field of human embryonic stem cell biology and to develop a well-trained pool of scientists in New Jersey proficient in hESC culture techniques with the goal of advancing New Jersey's leadership in stem cell research.

•Ronald Hart Ph.D. Rutgers University $275,590

Regulation of microRNA Gene Expression in Differentiating Neural Stem Cells

To understand and control differentiation of neural stem cells with the po-

tential to produce specific cell types for therapeutic transplant in brain trauma, stroke, spinal cord injury, Parkinson's and Alzheimer's disease.

•Hristo Houbaviy Ph.D. UMDNJ-RWJMS $300,000

MicroRNAs MiR-290-295 in Blastocyst-Derived Stem Cells and the Early Mouse Embryo

To understand stem cell development and lineage determination with the goal of expanding and improving knowledge of areas of stem cell biology currently not well understood.

•Ihor Lemischka Ph.D Princeton University $300,000

Genome-Wide Functional Analysis of ES Cell fate Regulation

To understand human embryonic stem cell decisions such as survival/death, renewal/determination and to understand how to maintain or induce specific cell fate with the goal of applying this knowledge to patient therapies.

•Randall McKinnon Ph.D. UMDNJ-RWJMS $300,000

Gliogenic Potential of Human Placental Stem Cells

To identify mechanisms of glial cell generation from human placental cells with the goal of identifying a potential alternative to embryonic stem cells for clinical trials. In collaboration with Celgene, a New Jersey-based biotech firm ranked sixth largest internationally.

•Kateri Moore DVM Princeton University $299,970

Interactive Mechanisms of Stem Cells and Microenvironments

To further understand the mechanisms of stem cell self-renewal and com-

mitment toward the purpose of developing new therapies or advancing existing therapies for use in drug development and for gene and cell therapy for immunological and other diseases.

•Richard Nowakowski Ph.D. UMDNJ-RWJMS $300,000

Molecular Circuitry of "Stemness" in the Developing CNS

To learn how to reprogram or teach transplanted cells how to generate the right type and number of necessary cells for cell-replacement therapies with the potential for replacing specific brain areas damaged by disease or injury.

•Robert Preti Ph.D. Amorcyte, Inc. $298,200

Bone Marrow Derived CD34 Cells for Treatment of Acute Myocardial Infarction

To produce a cell therapy product using bone marrow-derived cells for treatment of coronary damage following a heart attack and advance the company's federal Food and Drug Administration-approved clinical trials with the potential for new and more effective therapy for cardiac patients.

•Ling Qin Ph.D. UMDNJ-RWJMS $300,000

PTH-Mediated AGFR Signaling in Stromal Stem Cell Growth and Multidifferentiation

To conduct fundamental research using bone marrow stem cells with the potential to develop more effective treatments for low bone mass and similar disorders.

•Monica Roth Ph.D. UMDNJ-RWJMS $300,000

Selective Gene Delivery to Human Hematopoietic Stem Cells

To apply novel genetic screening approaches to stem cells with the potential of enhancing the ability to use stem cells and gene therapy in many clinical settings, including treating hematopoietic disorders and cancer.

•Junichi Sadoshima M.D. Ph.D. UMDNJ-New Jersey Medical School $300,000

Mechanisms of Mesenchymal Stem Cell Differentiation

To increase the efficiency of stem cell differentiation into cardiac myocytes by manipulating a particular signaling mechanism with the potential for developing an effective method to repair damaged heart tissues.

•Biagio Saitta Ph.D. The Coriell Institute for Medical Research $300,000

Role of Extracellular Matrix in Cord Blood Stem Cell Response to Cardiac Injury

To use stem cells derived from umbilical cord blood to study the molecular mechanisms of stem cells in repairing damaged areas of the heart with the potential to heal damaged tissue and preserve or regain function, offering an alternative to transplants which are possible but limited by the number of donors.

•Michael Shen Ph.D UMDNJ-RWJMS $300,000

Role of the Nodal signaling pathway in regulation of embryonic pluripotency

To enhance fundamental understanding of basic molecular functions in mice and human stem cells with the potential for improving manipulation of ES cells in culture for use in stem cell-based therapies including possible insights into the genesis and dysregulation of cancer stem cells.

•Thomas Shenk Ph.D. Princeton University $300,000

Isolation and Characterization of Life-Extended Human Cord Blood Cells

To produce populations of stem cells from human cord blood that can be used to study the molecular characteristics of such cells including how to modulate these growth responses *in vivo* and in culture with the potential to improve the clinical uses of stem cells.

•Yufang Shi, DVM, Ph.D. UMDNJ-RWJMS $300,000

Immunobiology of Mesenchymal Stem Cells

To investigate the mechanisms underlying stem cell mediated immune tolerance and its use in treatment of autoimmune disorders with the potential to lead to new treatment for many human diseases in which the immune system attacks the body, including MS and asthma.

•Jay Tischfield Ph.D Rutgers University $300,000

Genetic and Structural Analysis of Mouse ES Cells and their Derivatives

To study cultured ESC and confirm, monitor and regulate phenomena that would be deleterious to tissues derived from stems cells with the potential to prevent problems that could slow development of stem cell therapies.

(New Jersey Commission on Science & Technology website, 2008)

Massachusetts

Earmarked Funding:

- $12.9 million for facilities in Framingham
- $12.6 million for the I-93 interchange in Andover, Wilmington and Tewksbury
- $6.5 million for the William Stanley Business Park
- $10 million for a new nano and biomanufacturing facility at UMass Lowell
- $5.5 million for the Pioneer Valley Life Sciences Institute
- $1.1 million for three mobile labs in conjunction with Massachusetts Academy for Life Sciences
- $9.5 million for Tufts University
- $10 million for the Marine Biological Laboratory in Woods Hole
- $5 million for a regional incubation center in New Bedford in conjunction with UMass Dartmouth and Bristol Community College
- $5 million for a life sciences center at the Paul A. Dever State School in Taunton
- $10 million for the MA Small Business Matching Grant Fund
- $5 million for the MA Life Sciences Education Fund
- $90 million to UMass Worcester
- $95 million to UMass Amherst
- $10 million to UMass Boston in collaboration with the Dana-Farber Harvard Cancer Center
- $11.4 million to UMass Dartmouth

(McDermott Will & Emery, 2008)

New York

Planning Grants for Emerging Opportunities and Consortia Development for Stem Cell Research

RFA No. 0802071100

Lead Institution	PI	Amount	Title
Albert Einstein College Of Medicine	Eric Bouhassira	$120,000	New York Blood Disease Consortium
Brookhaven National Laboratory	Fritz A.Henn	$76,800	Planning Collaborative Research Between Cold Spring Harbor Laboratory, Stony Brook School of Medicine and Brookhaven National Laboratory
Cold Spring Harbor Laboratory	David J Stewart.	$118,920	Cold Spring Harbor Stem Cell Training Program
Columbia University - Morningside	Gordana Vunjak-Novakovic	$119,960	Molecular, Genetic and Biophysical Regulation of Human Stem Cells for Medical Impact
Columbia University Medical Center	James E. Goldman	$120,000	Stem Cell Biology: Novel Insights into Therapeutic Treatment of Human Disease
Cornell University	Alexander Yu Nikitin	$120,000	Stem Cells, Microenvironment and Cancer
Montefiore Medical Center	Sanjeev Gupta	$118,180	Liver Cell Transplantation
Mount Sinai School of Medicine	Ihor Lemischka	$120,000	System Biology and Stem Cells: An Integrated Multi-Disciplinary Strategy
New York Medical College	Thomas H. Hintze	$119,705	Translational Cardiovascular Stem Cell Consortium
Ordway Research Institute	Stewart Sell	$85,409	Stem Cells and Aging
Regenerative Research Foundation	Sally Temple	$120,000	Retinal Stem Cell Consortium
Roswell Park Cancer Institute	Andrei Gudkov	$120,000	Pharmacological Targeting of Stem Cells
SUNY - Downstate Medical Center	Olcay Batuman	$120,000	SUNY Downstate Vascular Stem Cell Genome Consortium
SUNY - Stony Brook University	Ira S. Cohen	$118,800	Mechanical And Electrical Regeneration of Heart With Stem Cells
SUNY - University at Albany	James Fossett	$119,948	New York Institute for Ethical Stem Cell Research (NYIESCR)
The New York Stem Cell Foundation	Susan L. Solomon	$119,797	Design of a New York Stem Cell Foundation Stem Cell Screening Lab
University of Rochester	Mark D. Noble	$76,751	Clinical Translation in Stem Cell Medicine: From Principles to Practice
Weill Medical College of Cornell University	M. Flint Beal	$117,127	Development of a Safe and Effective Stem Cell-Based Therapy of Parkinson's Disease

Appendix B: State Restrictions for Stem Cell Research and Use

Below is a table listing all of the states that have passed legislature in regards to research or use of stem cells. States not included have taken no official stance through legislature but may have implicit restrictions in place through political policies.

State/Jurisdiction Statute Section	**Specifically permits research on fetus/embryo**	**Restricts research on aborted fetus/ embryo**	**Consent provisions to conduct research on fetus/embryo[3]**	**Restricts research on fetus or embryo resulting from sources other than abortion**	**Restrictions of purchase/sale human tissue for research**
Arizona §§36-2302, 2303	No	Yes, prohibits research on aborted living/non-living embryo or fetus	No	Yes, prohibits the use of public monies for cloning for research	No
Arkansas §§20-17-802, 20-16-1001 to 1004	No	Yes, prohibits research on aborted live fetus	Yes, consent to conduct research on aborted fetus born dead	Yes, prohibits research on cloned embryos	Yes, prohibits sale of fetus/fetal tissue
California Health & Safety 2004 Proposition 71 §§ 123440, 24185, 12115-7, 125300-320	Yes, permits research on adult and embryonic stem cells from any source	Yes, prohibits research on aborted live fetus	Yes, consent to donate IVF embryo to research	Prohibits sale of embryos and oocytes; prohibits payment in excess of the amount of reimbursement of expenses to be made to any research subject to encourage her to produce human oocytes for the purposes of medical research	Yes, prohibits sale for the purpose of reproductive cloning or for stem cell research
Connecticut §§4-28e; 19a-32d et seq.	Yes, on embryos before gastrulation (a process during embryonic development)	No	Yes, consent to donate IVF embryo to research	No	Yes, prohibits payment for embryos, embryonic stem cells unfertilized eggs or sperm donated following IVF treatment
Florida §390.0111	No	Yes, prohibits on aborted live fetus	No	No	No
Illinois 720 ILCS 510/6, 510/12.1 Executive Order 6 (2005);410 ILCS 110/1 et seq.	Yes, permits research on embryonic stem cells, embryonic germ cells and adult stem cells from any source	Yes, prohibits on aborted living/ nonliving fetus	Yes, written consent to perform research on cells or tissues from a dead fetus other than from an abortion	Yes, prohibits research on fetus/fertilized embryo; prohibits funding under E.O. 6 (2005) of research on fetuses from induced abortions and the creation of embryos through the combination of gametes solely for the purpose of research	Yes, prohibits sale of fetus/fetal tissue; prohibits purchase or sale of embryonic or fetal cadaveric tissue for research but permits reimbursement for removal, storage and transportation for research
Indiana §35-46-5-1, 16-18-2-5.5	Yes, permits fetal stem cell research on placenta, cord blood, amniotic fluid or fetal tissue	Yes, prohibits research on aborted living/non-living embryo or fetus	Yes, consent required for fetal stem cell research	Yes, prohibits research on cloned embryos	Yes, prohibits sale of human ovum, zygote, embryo or fetus
Iowa §§707C.4	Yes, ensures that Iowa patients have access to stem cell therapies and cures and Iowa researchers may conduct stem cell research	No	No	No	Yes, prohibits transfer or receipt of the product of human reproductive cloning
Kentucky §436.026	No	No	No	No	Yes, prohibits sale of fetus/fetal tissue

Louisiana §14: 87.2	No	No	No	Yes, prohibits research on fetus/embryo in utero, in vitro fertilized embryo	No
Maine 22§1593	No	No	No	Yes, prohibits research on fetus/embryo born or extracted alive, only applies to in vitro fertilized embryos post-implantation	Yes, prohibits sale of fetus/fetal tissue
Maryland 83A§5-2B-01 et seq.	Yes, permits research on adult and embryonic stem cells	No	Yes, written consent to donate unused IVF material to research	Yes, prohibits donation of unused oocytes for state funded stem cell research; cloning of an organism beyond the embryonic stage is prohibited	Yes, prohibits valuable consideration for the donation or production of IVF material
Massachusetts 112§12J, 2005 SB 2039	Yes, on embryos that have not experienced more than 14 days of development (not including days frozen)	Yes, prohibits research on embryo/live fetus	Yes, written consent to perform research on a dead fetus and informed consent to donate egg, sperm, or unused preimplantation embryos created for IVF	Yes, prohibits research on live embryo or fetus; also prohibits creation of fertilized embryo solely for research	Yes, prohibits sale of neonate, embryo or fetus for illegal purposes; prohibits sale of embryos, gametes or cadaveric tissue for research
Michigan §§333.2687-2688, §§333.16274-16275, 333.20197, 333.26401-26403, 750.430a	No	Yes, live embryo/ fetus	Yes, written consent of mother to donate dead embryo, fetus or neonate to research	Yes, prohibits research on a live embryo or fetus, cloned embryo	No
Minnesota §§145.421, 422	No	No	No	Yes, prohibits research on a live embryo or fetus up to 265 days post fertilization	Yes, permits the sale/ purchase of cell culture lines from nonliving human conceptus
Missouri §§188.036, 037	No	Yes, prohibits research on a fetus alive pre-abortion	No	No	Yes, prohibits receipt of valuable consideration for aborted fetal organs or tissue
Montana §50-20-108(3)	No	Yes, prohibits research on a live fetus	No	No	No
Nebraska §§28-342, 346, 71-7606	No	Yes, prohibits research on aborted live fetus or the use of state funds for research on fetal tissue obtained from an abortion	No	Yes, limits the use of state funds for embryonic stem cell research; restrictions only apply to state healthcare cash funds provided by tobacco settlement dollars	Yes, prohibits sale, distribution or donation of viable aborted child
New Hampshire §§168-B:1, 15	No	No	No	Yes, prohibits the maintenance of a unfrozen fertilized pre-embryo past 14 days	Yes
New Jersey C.26:2Z-1 et seq.; C.2C:11A-1	Yes	No	Yes	No	No
New Mexico §24-9A-1, 3, 5	No	No	No	Yes, prohibits research on a fetus/embryo born or extracted alive, only applies to in vitro fertilized embryos post-implantation	Yes, prohibits abortion for the purpose of selling the fetus to researchers
New York Public Health Law Article 2, Title 5A	Yes, permits research on adult and embryonic stem cells from any source	No	No		
North Dakota §14-02.2-01, 2; 2003 HB 1424	No	Yes, prohibits research on a living/non-living embryo or fetus	Yes, requires consent to conduct research on a nonliving fetus or embryo other than from an abortion	Yes, prohibits research on a fetus born or extracted alive; cloned embryos	Yes, prohibits the sale of a fetus to be used for illegal purposes
Ohio §2919.14	No	Yes, prohibits research on a living/non-living embryo or fetus	No	No	Yes, prohibits sale of fetus or fetal remains from an abortion

Oklahoma 63 §1-735	No	Yes, prohibits research on a fetus/embryo	No	No	Yes, prohibits sale of fetus or fetal remains
Pennsylvania 18 §§3203, 3216	No	Yes, prohibits research on a live embryo or fetus	Consideration may not be given to mothers consenting to research; in cases involving abortion, consent must be provided after decision to abort	No	Yes, consideration may not be given to mothers consenting to research or other transferring tissue except for expenses involved in actual retrieval, storage, etc.
Rhode Island §11-54-1	No	No	Yes	Yes, prohibits research on a fetus/embryo born or extracted alive, only applies to in vitro fertilized embryos post-implantation	Yes, prohibits sale of neonate, embryo or fetus for illegal purposes
South Dakota §§34-14-16, 17, 20; 34-23A-17	No	Yes, prohibits research on a living/non-living embryo or fetus	No	Yes, prohibits research on embryo outside of a woman's body; research on cells or tissues derived from an embryo outside a woman's body	Yes, prohibits sale of embryo
Tennessee §39-15-208	No	No	Yes, consent required to conduct research on aborted fetus	No	Yes, prohibits sale of aborted fetus
Texas Penal Code §48.02	No	No	No	No	Prohibits sale of fetus/fetal tissue
Utah §§76-7-301, 310	No	No	No	Yes, prohibits research on a live fetus, fertilized embryo post-implantation[1]	Yes, prohibits sale of fetus/fetal tissue; also prohibits sale of live unborn children, which is not defined, but are referred to in abortion statute[1]
Virginia §32.1-162.32-2	No	No	No	May prohibit research on a cloned embryo or fetus[2]	Yes, prohibits shipping or receiving of the product of human cloning for commerce[2]
Wyoming §35-6-115	No	No	No	No	Yes, prohibits sale, distribution or donation of live or viable aborted child, defined to include embryos, for experimentation