

**Stem Cell Research and Governmental Policy: Taking a New
Look at Both the Dollars and the Sense of it All**

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Senior Honors Thesis
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December 8, 2006

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Thesis Statement: Despite the stigma surrounding stem cell research, the many potential benefits of stem cell research in the scientific, clinical, and medical settings outweigh the negatives. Because of this, stem cell research, especially embryonic stem cell research, is vital to the continued growth of science and medicine. Therefore, there should be increased funding for embryonic stem cell research and a loosening of federal restrictions in order for stem cell research to fulfill its potential.

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Are The Potential Benefits of Stem Cell Research Great Enough to Increase Federal Funding And Loosen Federal Restrictions?

The little girl laughed as she flew down the slide after her friends, as care-free as a bird on a warm, sunny day. She jumped, she ran, and she played as any other seven year-old would. At first glance, there seems to be nothing significant about this happy child. However, over two years ago, this little girl could not jump, run, or play with her friends. She was only able to sit and watch her friends play, unable to join in because of the helmet she had to wear on her head night and day. More than two years prior, this little girl suffered a traumatic head injury from a fall that left her with fractures in her skull.¹ Surgery to repair her damaged skull proved unsuccessful, and the exposed brain tissue and infection left her with no choice but to wear a helmet to protect her delicate brain from further injury. She would still be wearing that helmet today if it was not for the therapeutic use of stem cells.

The original surgery tried to replace the fractured pieces of her skull. However, the bones did not kit together, and the little girl was left with holes in her skull. As a last resort, surgeons removed bone from the hip, ground the bone into small pieces, and placed it into a graft that would cover the affected areas of the skull.² Stem cells extracted from her fat tissue were also placed into the graft with the bone, and everything was held together with fibrin glue, which is produced by the body to initiate the healing process.³ This graft, containing some of her bone cells, fat-derived stem cells, and fibrin glue were

¹ Stefan Lendeckel, Andreas Jödicke, Petros Christophis, Kathrin Heidinger, Jan Wolff, John K. Fraser, Marc H. Hedrick, Lars Berthold, and Hans-Peter Howaldt, "Autologous stem cells (adipose) and fibrin glue used to treat widespread traumatic calvarial defects: case report," *Journal of Cranio-Maxillofacial Surgery* 32 (2004), pp. 370-371.

² *Ibid.*

³ M. Valbonesi, "Fibrin glues of human origin," *Best Pract. Res. Clin. Haematol.* 19, no. 1 (2006): p. 191.

placed in the openings, and everyone held their breaths and watched. Three months after the surgery, CT scans showed that bone had re-grown and filled in the openings in her skull.⁴ With her delicate brain once again protected by a solid layer of bone, the little girl no longer had to wear the helmet, and could play like a normal seven year-old should.

Without the use of stem cells, the openings in this little girl's head may never have healed, resulting in her wearing the helmet for the rest of her life or possibly dying from infection or damage to her brain. Using stem cells along with bone tissue allowed new bone formation to cover the openings in her skull. This medical miracle has allowed this little girl to live a healthy, normal life; a life she would not have had if it had not been for stem cell research.

Stem cell research has become an area of avid interest for scientists, medical professionals, the government, religious groups, and the public alike in recent years. However, interest in stem cells had originated decades ago when the first reports of stem cells in mouse embryos were published in the early 1960's.⁵ Stem cells were of interest to mid-twentieth century research scientists because they wanted to know what type of cells were responsible for the development of the embryo through the loss of pluripotency, which is the cell's potential ability to become more than one cell type. Since this first interest in stem cells, researchers have not only found cells that are responsible for the development of an embryo; they have also found stem cells that reside in umbilical cord blood as well as adult tissues.

⁴ Lendeckel, Jödicke, Christophis, Heidinger, Wolff, Fraser, Hedrick, Derthold, and Howaldt, *Journal of Cranio-Maxillofacial Surgery*, pp. 370-371.

⁵ Janet Rossant, PhD, "Embryonic Stem Cells in Perspective," in *Essentials of Stem Cell Biology* (California: Elsevier Academic Press, 2006), p. xix.

The interest in stem cells today includes, but is not solely based upon, the fact that stem cells exist in many different places. How these different types of stem cells maintain their undifferentiated characteristics and how and what types of cells they can differentiate into by changing the stem cell's characteristics through genetic modification is currently under investigation. Positives and negatives surrounding stem cells, their sources, and their uses have been brought to the forefront as a result of this research. Many of these social stigmas surrounding stem cell research focus on embryonic stem cells. The possible creation and destruction of embryos during research have led to moral and ethical objections, especially within the religious sector. Other negatives surrounding stem cell research, including the introduction of foreign substances into the body and the possibility of causing additional defects in the body, also deter stem cell research.

Despite the controversy that surrounds stem cell research today, there are many potential benefits that support the continuation of all forms of stem cell research. Scientists have begun to open the door on developing uses for stem cells, which may have many benefits in the scientific and medical spheres. Some of these include the possibility of preventing or curing cancer and other deadly diseases, repairing damage to the body, and restoring function to tissues and organs. These potential benefits would allow people to have a greater quality of life, no matter what age.

The biggest effect on stem cell research in the United States today is governmental policy and funding. Currently, governmental policy has strict guidelines and restrictions on stem cell research. Governmental funding is limited to only certain stem cell lines. The future of stem cell research in the United States is in the hands of the

government and the policies enacted to regulate what cell lines can be used and what can be done with those lines. The potential benefits of stem cell research outweigh the negatives. However, in order for the development of medical advances, governmental restrictions need to be lifted and federal support for stem cell therapies needs to be increased.

This study will illustrate the importance of stem cell research to science and medicine. It will also cover the necessity of changing governmental policy and funding to further develop stem cell programs and applications. First, a description of stem cells, their unique characteristics, differing source locations, and an overview of their potential role in science and medicine will be examined in order to provide background information and illustrate reasons why there is an avid interest in stem cells.

The potential negatives of stem cell research, which play a role in current governmental policy, will be then examined. These stem from moral and ethical issues, such as the creation and destruction of embryos, and the dangers of using stem cells to treat and/or prevent disease. An analysis of these issues will show that they may provide some legitimate cause for concern in the continuation of stem cell research.

Advantages of stem cell research will also be examined. These potential benefits may include development of cures for deadly diseases as well as the ability to repair damaged tissue, restore organ function, and correct birth defects. Analysis of these benefits will show that the advantages of stem cell research outweigh any potential drawbacks.

The current governmental policies concerning stem cell research and the current status of stem cell lines in use that are funded by the government will then be analyzed.

This analysis will establish the current beliefs concerning stem cells and the current public and federal position concerning funding for stem cell research. In conclusion, final analysis of the advantages and benefits of stem cell research will show that despite the negatives of stem cell research, a loosening of federal restrictions and an increase in federal funding is necessary for potential benefits of stem cell research and advances in medicine to be achieved.

Stem Cells

Stem cell research is ever evolving as new information about established stem cells is discovered and new sources of stem cells are identified. A stem cell can generally be defined as “clonal, self-renewing entity that is multipotent and thus can generate several differentiated cell types.”⁶ In other words, a stem cell is a cell that produces an identical copy of itself countless times correctly when it divides. This same stem cell can differentiate or become more than one specific cell type. The capacity for “self-renewal” allows for a potential continuous source of cells. The ability to produce offspring cells that can differentiate allows for more tissues to obtain new cells when dead cells need to be replaced or when damage tissues need to be repaired. These two broad characteristics of all stem cells, self-renewal and differentiation, provide the potential ability to use these stem cells in many different therapeutic treatments.

As the different types of stem cells are examined, however, more specific characteristics that define each specific stem cell type become apparent. The three broad types of stem cells are embryonic, umbilical cord blood, and adult stem cells. Human

⁶ Douglas Melton, PhD and Chad Cowen, PhD, “‘Stemness’: Definitions, Criteria, and Standards,” in *Essentials of Stem Cell Biology* (California: Elsevier Academic Press, 2006), p. xxvi.

embryonic stem cells are derived from the inner cell mass of the developing blastocyst. A blastocyst is a ball of cells that contains an inner cavity. It forms after fertilization of the egg but before implantation into the uterine wall.⁷ Embryonic stem cells originate from the inner cell mass of the blastocyst, which in turn produces all the body's tissues. It is logical, then, that embryonic stem cells would also exhibit the ability to become all of the cell types in the body.⁸ Specifically, embryonic stem cells have to be capable of self-renewal and differentiation into many cell types in vitro and in vivo, have to proliferate or reproduce excessively in culture, have markers on the cell surface specific for pluripotent cells, and have to be able to withstand being frozen and thawed.⁹

Umbilical cord blood stem cells are found in the umbilical cords that connect the mother to the newborn baby. Umbilical cord blood stem cells, also called cord blood stem cells, are specifically capable of self-renewal, proliferation, and homing or migrating to certain tissues due to molecular signals.¹⁰ Currently, cord blood stem cells are unique in that they can withstand long periods of being frozen without a decrease in their potency as stem cells.¹¹ Cord blood stem cells have also been shown to provide less graft vs. host diseases and complications than other stem cells when transplanted into children.¹² This means that if cord blood stem cells are transplanted into a different person from where they were obtained, there is less of a chance that the recipient's immune system will reject and kill the cells.

⁷ V. Papaioannou, "Stem cells and differentiation," *Differentiation* 68, (2001), pp.153-154.

⁸ Melton and Cowen, *Stem Cell Biology*, p. xxvi.

⁹ *Ibid.*, p. xxix.

¹⁰ Hal Broxmeyer, "Cord Blood Hematopoietic Stem and Progenitor Cells," in *Essentials of Stem Cell Biology* (California: Elsevier Academic Press, 2006), p. 135.

¹¹ Broxmeyer, *Stem Cell Biology*, p. 133.

¹² *Ibid.*

Adult stem cells are a broad category of stem cells which are located in many different adult tissues. Some of the many adult stem cells include mesenchymal stem cells, neural stem cells, epithelial or skin stem cells, hepatic or liver stem cells, and hematopoietic stem cells of the bone marrow. Adult stem cells are more specifically defined as:

A small subpopulation of the proliferating compartment, consisting of relatively undifferentiated proliferative cells that maintain their population size when they divide, while at the same time producing progeny that enter a dividing transit population within which further rounds of cell division occur, together with differentiation events, resulting in the production of the various differentiated function cells required of the tissue.¹³

Succinctly, this means that adult stem cells exist in small groups and are mostly undifferentiated, meaning the cells have the capability to change into one or more cell types over time. Furthermore, adult stem cells are capable of self-renewal and can also produce offspring that will become one or more cell types.

While adult stem cells can be pushed to differentiate into different cell types, they cannot become every cell type in the body. This limitation is a result of the fact that adult stem cells of different tissues do have some of the characteristics of that tissue. This results in the adult stem cell offspring only being able to develop into only cell types related to the tissue of origin. For example, neuronal stem cells may develop into nerve cells of the brain or spinal cord, but not into cells of other organs, such as the liver. Besides being able to self-renew, produce differentiated progeny, and proliferate, adult stem cells are also capable of homing to specific environments in the body and

¹³ C. S. Potten and J. W. Wilson, "The Development of Epithelial Stem Cell Concepts," in *Essentials of Stem Cell Biology* (California: Elsevier Academic Press, 2006), p. 12.

regenerating functional tissue after injury.¹⁴ These additional functions of adult stem cells make them ideal candidates for therapeutic stem cell medicine because they may be able to be used in specific patients to help rebuild damaged tissue, providing the patient with a better quality of life.

It is evident that each type of stem cell has distinct advantages for use in a medical setting because of the many characteristics and functions each possess. Because stem cells can become many different types of cells, they provide researchers with the ability to look at how a cell divides, and what factors are necessary for cells to become specialized. Because stem cells can proliferate as well as produce offspring that can differentiate into many types of cells, stem cells may have a future in preventing, fighting, or curing current medical issues faced today.

Potential Negatives of Stem Cell Research

Despite the potential profit of conducting stem cell research, there are several controversial issues surrounding stem cell research and its future relevance to science and medicine. The main source of contention is borne from moral and ethical objections, especially to embryonic stem cell research. Moral and ethical objections concerns come into play because obtaining embryonic stem cells results in the destruction of the embryo. This is further complicated by the notion of creating embryos solely for the purpose of obtaining stem cells.

The status of an embryo plays a vital role in determining if embryonic stem cell research is morally and ethically acceptable. The question: “Are embryos human

¹⁴ Ingo Roeder, Joerg Galle, and Markus Loeffler, “Theoretical Concepts of Tissue Stem-Cell Organization,” in *Tissue Stem Cells* (New York: Taylor & Francis Group, 2006), p. 18.

beings?” is still debated among scholars, scientists, politicians, and religious leaders alike. In order to shed light on this difficult question, one must evaluate the development of an embryo from conception, as well as religious beliefs on when an embryo “becomes” an individual, unique human being. If an embryo is considered to be a human being, creating or destroying embryos for scientific research may be considered morally and ethically wrong. However, if it can be determined that an embryo is not an individual entity at the time the inner cell mass of the blastocyst is harvested, there will be considerably less moral and ethical objection to embryonic stem cell research.

Biologically, there are many steps in the process resulting in the formation of an embryo from a fertilized ovum or egg. Before an ovum, or egg, can be fertilized, a sperm cell has to undergo capacitation, which is when molecules in the female reproductive tract bind to receptors on the sperm cell, causing the sperm cell to become metabolically active.¹⁵ After capacitation, which can take up to seven hours in humans, the sperm cell can then break through the zona pellucida, the extracellular matrix surrounding the egg, and fertilize the egg.¹⁶ Once the ovum is fertilized, the newly formed diploid zygote begins the process of cleavage, which is cell division without cell growth, until the eight to sixteen cell stages, when compaction produces a tightly joined ball of cells.¹⁷ “Although the cells become compacted here, there is yet no predetermination of any one cell to become a specific entity or part of an entity.”¹⁸ A lack of predetermination of the

¹⁵ Neil A. Campbell and Jane B. Reece, *Biology, Sixth Edition* (San Francisco: Benjamin Cummings, 2002), p. 1002.

¹⁶ Campbell and Reece, *Biology*, p. 1002.

¹⁷ Susana M. Chuva de Sousa Lopes and Christine L. Mummery, “Differentiation in Early Development,” in *Essentials of Stem Cell Biology* (California: Elsevier Academic Press, 2006), p. 101.

¹⁸ Thomas A. Shannon and Allan B. Wolter, OFM, “Reflections on the Moral Status of the Pre-embryo,” in *Contemporary Issues in Bioethics: A Catholic Perspective* (Lanham, Maryland: Rowman & Littlefield Publishers, Inc., 2005), p. 71.

cells means that these cells are still undifferentiated, meaning these cells have the capability of forming one or more completely full organisms.

After compaction occurs, the blastocyst forms and continues to divide before it is implanted into the uterine wall. At this stage, the blastocyst consists of an outside wall of cells, the trophoblast, a group of cells located on the inside of the trophoblast, the inner cell mass (ICM), and a hollow fluid-filled cavity, the blastocoel.¹⁹ At implantation of the embryo, the embryonic cells of the ICM “lose their ability to contribute to the embryo when introduced directly into a host blastocyst.”²⁰ Basically, once the embryo is implanted into the uterine wall, the cells of the embryo begin to change into cells that will make up a fully formed human being and no longer have the ability to become any cell type. What is most significant about this event is that from the ‘blastocyst state to the completion of implantation the pre-embryo is capable of dividing into multiple entities.’²¹ Therefore, before implantation, the dividing cells of the early zygote and blastocyst can separate to form what would become identical twins. This suggests that until implantation into the uterus, the embryo is not necessarily one individual. Biologically then, an embryo may not become an actual individual until after implantation into the uterine wall has occurred because the embryo still contains the potential to develop into more than one individual. Therefore, these facts suggest that since the un-implanted early embryo can become more than one individual or can become one individual from two separate entities, the un-implanted early embryo should not have the same status as an actual human being.

¹⁹ Campbell and Reece, *Biology*, pp. 1010-1011.

²⁰ Chuva de Sousa Lopes and Mummery, *Stem Cell Biology*, p.104.

²¹ Bruce M. Carlson, *Patten's Foundations of Embryology*, 5th ed. (New York: McGraw-Hill, 1988), p. 134, in *Contemporary Issues in Bioethics: A Catholic Perspective* (Lanham, Maryland: Rowman & Littlefield Publishers, Inc., 2005), p. 71.

In addition to the biological view of the early embryo, there are many different views as to when an embryo becomes a human being along a religious perspective. Major religions of the world, including Hinduism, Buddhism, Islam, Judaism, and the many branches of Christianity all view conception and the embryo differently with regard to when life begins and as to whether an embryo should be treated as a human being. Hindu belief states that “human life begins prior to conception,”²² and that “human incarnation offers a unique opportunity to influence the future of an individual.”²³ These Hindu beliefs suggest that to many Hindus, an embryo at conception would indeed be an individual human being with the same rights of any human that had already been born.

Buddhist beliefs are both similar and different to the beliefs held in Hinduism. Buddhists believe in reincarnation like Hindus; however, they believe that “a soul has some choice as to where it will be reincarnated.”²⁴ This suggests that embryos used for embryonic stem cell research may never have a soul inhabit them, as a soul would bypass an embryo to be used in research in favor of an embryo that was allowed to fully develop and be born. Therefore, the beliefs of Buddhism imply that embryos at the time stem cells are removed do not have the same status as an individual human being.

Islamic tradition also discusses the status of an embryo at conception and during development. Overall, Muslims of both Sunni and Shi’i sects believe that there are two stages to pregnancy. “The first stage, pre-ensoulment, is human biological life but not yet human personal life. It is only after the fourth month (120 days, or the time of

²² Margaret A. Farley, “Stem Cell Research: Religious Considerations,” in *Essentials of Stem Cell Biology* (California: Elsevier Academic Press, 2006), p. 496.

²³ *Ibid.*

²⁴ *Ibid.*, p. 497.

“quickenings”) that the ‘biological human’ becomes a ‘moral person.’”²⁵ Therefore, the embryo at the time embryonic stem cells are removed would be respected by Muslims but not considered as an individual human being.

The belief of some branches of Judaism, especially Reform Judaism, concerning the status of an embryo is similar to that of many Muslims. Jewish law states that inside a woman’s womb, the embryo has legal status and should be respected, but that legal status is not the same as the legal status given to a person already born.²⁶ Furthermore, it is believed that “during the first 40 days of gestation, *in utero* embryos are only like “water.” They are “non-souled,” with only a liminal status.”²⁷ Jewish law and Jewish beliefs show that to many Jews, early embryos need not be treated as actual human individuals because they are not actual human beings yet, but that embryos need to be treated with respect. Therefore, an embryo used for embryonic stem cell research would not have the status of an individual human being.

The many branches of Christianity have differing views when it comes to the status of the embryo, especially concerning embryonic stem cell research. Most Orthodox Churches believe that as people are created in the image of God, they have to grow into life on earth and participate fully in order to achieve the destiny God has laid out for them.²⁸ Because of this belief, early embryos, from the moment of conception, are considered potential people that have the right to grow and develop and live just as any human being already born has. This view that the embryo is sacred and a potential person

²⁵ Farley, *Stem Cell Biology*, p.497.

²⁶ *Ibid.*

²⁷ *Ibid.*

²⁸ Farley, *Stem Cell Biology*, p. 498.

right from the moment of conception grants the early embryo full status as an individual human being.

Catholicism also stresses the belief that at conception, an embryo is a unique human being. The Roman Catholic Church believes that the creation of new things, including an embryo, is a divine activity,²⁹ and that “the process toward authentic human personhood begins with the zygote, which is committed to a developmental course that will ultimately lead to a human person.”³⁰ Because the creation of an embryo is considered a divine and sacred act that produces a unique individual human being right at conception, any embryo, no matter what day old, has the status as a fully formed and already born human.

While conservative Protestant Churches follow similar beliefs as the Orthodox and Roman Catholic Churches, more liberal Protestant Churches believe that an embryo has the potential to become a human being as it develops from a ball of cells into a fully formed fetus.³¹ However, these Protestants also believe that while the embryo should be respected because of its *potentiality*, the embryo should not be awarded the same status of a human individual.³² These beliefs show that unlike other Christian churches, some Protestant Churches do not grant the embryo the same status as a human being.

These many differing views on the status of an embryo, both from a biological perspective and a religious perspective, suggest a few conclusions about the moral status of embryos. The most important conclusion is that no concise, universal agreement can

²⁹ Farley, *Stem Cell Biology*, p. 499.

³⁰ Kristina Hug, “Therapeutic perspectives of human embryonic stem cell research *versus* the moral status of a human embryo – does one have to be compromised for the other?” *Medicina (Kaunas)* 42(2) (2006), p.111.

³¹ *Ibid.*

³² Farley, *Stem Cell Biology*, p.498.

be found concerning the status of the embryo. Not only do religious and biological views differ, each religion believes different things about the embryo. Without consensus on the status of the embryo, there is no way to eliminate moral and ethical controversy over the destruction of an embryo. With the status of the embryo uncertain for the foreseeable future, embryonic stem cell research will continue to be seen as immoral and ethically wrong by certain groups because it entails the creation and destruction of embryos.

The destruction of embryos to obtain embryonic stem cells is seen as morally and ethically wrong because, as discussed previously, certain religions believe that the embryo has the same moral status as a human being. As the blastocyst is located within the developing embryo, the total embryo has to be destroyed to obtain embryonic stem cells. According to Hinduism, Orthodox Christianity, Catholicism, and certain Protestant Churches, this destruction of the embryo to obtain embryonic stem cells is equal to murder. As all of these religions and other religions promote the well-being of people, the purposeful killing of an individual for the good of another, or other, individuals is not justified. Embryonic stem cell research even further violates the principle of not harming others because the embryo cannot consent to being killed in order for research to be done to help mankind.³³ Because of the human status given to stem cells by some religions, the destruction of embryos is seen as immoral, and therefore embryonic stem cell research should not be continued.

Embryos also have to be created in order to obtain the necessary embryonic stem cells to conduct stem cell research. This creation of embryos has also lead to moral and ethical controversy. Some individuals believe that creating an embryo just to destroy it is

³³ Ronald M. Green, "Ethical Considerations," in *Essentials of Stem Cell Biology* (California: Elsevier Academic Press, 2006), p. 489.

morally wrong, and therefore also object to embryonic stem cell research.³⁴ The creation of embryos occurs regularly as part of the *in vitro* fertilization process utilized by couples who cannot otherwise have children. Many more embryos are created than are used during the process of *in vitro* fertilization. Any “left over” embryos are often frozen, discarded, or used for embryonic stem cell research. Aside from reproductive purpose, embryos have also been created purposely for embryonic stem cell research. Many people see this creation of embryos specifically for research as wrong because it allows one to “play God,” something human beings should have no right to do.

It is evident then that there is moral and ethical controversy surrounding embryonic stem cell research. Because many religions and people believe that an embryo has equal rights as a human being, obtaining embryonic stem cells and conducting research with only the potential to help people does not justify the creation and destruction of life for these individuals. In almost every culture, the murder of an individual, with very few exceptions, is considered an immoral act. This then can make embryonic stem cell research, where the “individual” is destroyed, out to be immoral as well. It is clear then that moral and ethical considerations concerning the moral status of an embryo, and the creation and destruction of embryos are a significant concern of stem cell research, and suggests that embryonic stem cell research should be stopped.

Despite this potential roadblock to stem cell research, there is an alternative to the embryonic stem cell problem that would greatly eliminate the moral and ethical objections to stem cell research overall. By limiting stem cell research to just adult and cord blood stem cells, embryonic stem cell research, and any moral and ethical objections that are inherent to embryonic stem cells, can be bypassed. As stated earlier, adult stem

³⁴ Green, *Stem Cell Biology*, p. 491.

cells are found in many adult tissues and can be coaxed into more than one cell type. Umbilical cord blood stem cells are found in the umbilical cord blood of newly born children and can also be influenced to form different cell lineages. Both of these sources of stem cells offer a way to conduct stem cell research without potentially killing a human being, or potential human being, while also gaining the permission of the individual whose cells would be used.

At first glance, it seems that both umbilical cord blood stem cells and adult stem cells are equally viable options to embryonic stem cells. It can be asked then whether or not embryonic stem cells are necessary for further stem cell research. However, while umbilical cord blood stem cells and adult stem cells provide other options for cell sources, they currently do not have the range of differentiation capabilities that embryonic stem cells have. It is true that umbilical cord blood stem cells and adult stem cells have the ability to become many different cell types if treated with the correct factors. Even more importantly is the fact that,

Although the adult stem cells and umbilical cord blood stem cells might exhibit an uncontrolled growth in a specific microenvironment and enhance telomerase activity, they generally show a more restricted differentiation potential and give rise to a more limited number of distinct cell progenitors.³⁵

In other words, when grown in lab Petri dishes treated with specific factors for each type of stem cell, adult and cord blood stem cells, like other stem cells, can continuously grow and divide, producing exact copies of the original stem cells and causing an increase in the number of stem cells present. However, when these cells are treated with specific factors known to cause the cells to differentiate into specific cell types, both adult and

³⁵ Murielle Mimeault and Surinder K. Batra, "Recent Advances on the Significance of Stem Cells in Tissue Regeneration and Cancer Therapies," *Stem Cells*, (North Carolina: AlphaMed Press, 2006), p. 7.

cord blood stem cells are limited in the number of different cell types they can become. Because of these limitations, these two sources of stem cells cannot provide research scientists with the same capabilities to differentiate and therefore the same research and therapeutic power as embryonic stem cells can.

While it is clear that the moral and ethical controversy surrounding embryonic stem cell research is the main negative to the continuation of stem cell research, there are other negatives that come to light under further examination. One such negative is the possibility for stem cells to actually harm the patient receiving the stem cells instead of helping the patient. Potential harm to patients can originate from a number of sources, including the medium stem cells are cultured in as well as the stem cells themselves.

Currently, most stem cell lines are derived, meaning they are originally grown from one or more original stem cells, and are continued to be grown on primary mouse embryo fibroblast monolayers.³⁶ Therefore, stem cells used in research are currently being grown, maintained, and experimented on in a culture medium that is not of human origin; rather, the culture medium is comprised of mouse fibroblast cells, as well as other factors. This provides the potential for certain retroviruses and other pathogens to enter the stem cells and consequently, be transferred into the human patient.³⁷ The implication of this fact is that different viruses, bacteria, and other pathogens that are currently specific to mice may be introduced into the human population if stem cells put into a patient contained these mouse pathogens. Once in the human body, there is no real way of knowing just what these foreign pathogens may do to the cells and tissues of the

³⁶ Irina Klimanskaya and Jill McMahon, "Approaches for Derivation and Maintenance of Human ES Cells: Detailed Procedures and Alternatives," in *Essentials of Stem Cell Biology* (California: Elsevier Academic Press, 2006), p. 288.

³⁷ Green, *Stem Cell Biology*, p. 493.

human body. Stem cells may be able to be infected with certain mouse pathogens because “human embryonic stem cells are prone to spontaneous differentiation under unfavorable conditions,”³⁸ which simply adding antibiotics to the culture may cause. Because antibiotics cannot be used in stem cell culture media except for extreme circumstances, foreign pathogens may be allowed to survive in culture and infect the cultured stem cells.

Although the concern of introducing foreign pathogens into the human body via stem cells is genuine, this should not deter further research on stem cells. In fact, recent research has shown that stem cells can be grown and maintained on feeders of human origin. Feeders are a layer of cells that produce the necessary factors to maintain a healthy stem cell culture. One new type of culture system consists of growing and maintaining embryonic stem cells in the presence of human bone marrow stem cells.³⁹ This means that embryonic stem cells are being grown in a culture consisting of human bone marrow stem cells. These bone marrow stem cells provide the necessary nutrients to maintain the embryonic stem cells while not causing the embryonic stem cells to differentiate. Another type of culture condition that does not require animal cells uses embryonic stem cells as feeder cells. These embryonic stem cells are differentiated into fibroblast-like cells, the same type of cells used in cultures with mice cells.⁴⁰ These differentiated embryonic stem cells are then used to support, grow, and maintain undifferentiated embryonic stem cells. In both cases, new stem cell lines can be developed, grown, and experimented on without ever having to use non-human cells or

³⁸ Klimanskaya and McMahon, *Stem Cell Biology*, p. 288.

³⁹ Linzhao Cheng, Holly Hammond, Zhaohui Ye, Xiangcan Zhan, and Bautam Dravid, “Human Adult Marrow Cells Support Prolonged Expansion of Human Embryonic Stem Cells in Culture,” *Stem Cells* 21 (2003), p. 131.

⁴⁰ Petra Stojkovic, Majlinda Lako, Rebecca Stewart, Stefan Przyborski, Lyle Armstrong, Jerome Evans, Alison Murdoch, Tom Strachan, and Miodrag Stojkovic, “An Autogeneic Feeder Cell System That Efficiently Supports Growth of Undifferentiated Human Embryonic Stem Cells,” *Stem Cells* 23 (2005), p. 306.

products. Therefore, the risk of transferring non-human viruses or pathogens into human patients can be eliminated. As a result, as more stem cell lines are being developed and grown using these new culture systems, this potential negative of stem cell research will no longer exist.

While introducing foreign pathogens into the human body through stem cells is a potential source of harm for only the near future, harm to patients treated with stem cells may also originate from the stem cells themselves. Stem cells, especially adult stem cells, contain markers specific to each individual that mark the cells as “self” to that specific individual, just as all cells in each individual are marked. These identifying markers tell a person’s immune system not to consider the cells as foreign, keeping them from being destroyed. As in the case with transplants, those specific markers may identify the newly implanted cells as “non-self” to the recipient, causing host rejection or “graft-versus-host disease.”⁴¹ Therefore, even if the introduced stem cells would help the patient, the patient’s immune system could reject and destroy those cells if they are viewed as “foreign,” and could cause damage to their own tissues or even worse tissue failure.

Using adult stem cells in treatment will always pose the threat of recipient rejection unless the stem cells used were taken from the actual patient. This method of treating people may at first be too costly to justify or use widely as a form of treatment for certain diseases and repairing damaged tissues or organs. However, embryonic stem cells do not carry the magnitude of risk of recipient rejection because the stem cells have not developed those specific markers that identify the cells to the body as “self.” Therefore, embryonic stem cells become an even more desirable form of stem cells to be

⁴¹ Green, *Stem Cell Biology*, p. 493.

used to treat people in years to come because they do not carry the immune rejection risks that adult stem cells do.

Stem cells themselves also have the potential to cause harm to the recipient “by behaving in unexpected ways when transplanted into the human body.”⁴² Stem cells may travel to an unintended area of the body, possibly causing damage to those tissues if they developed into a different type of cell or if they caused the death of functional cells. Because stem cells can divide continuously, they may also divide out of control, resulting in cancer.⁴³ This developing tumor could metastasize, resulting in the cells “invading surrounding normal tissue and spreading throughout the body via the circulatory or lymphatic systems.”⁴⁴ Furthermore, recent clinical trials using stem cells to improve heart function and strength have shown mixed results, with some trials showing significant improvement in the heart’s ability to pump blood, while another trial did not show any benefit to patients.⁴⁵ These trials show that while stem cells have the potential to help improve organ function in humans, the exact technique or method for using stem cells is not completely determined. It is evident that a great deal of research concerning stem cells has yet to be carried out in order to determine how stem cells can be used and what needs to be done to prevent harm to the patient.

All of these potential sources of harm to recipient patients are plausible concerns of using stem cells for medical therapies. One could claim that stem cells should not be used in experimental treatments to help people who suffer from disease or organ damage. However, these potential sources of harm should not be seen as sufficient evidence to

⁴² Green, *Stem Cell Biology*, p. 493.

⁴³ *Ibid.*

⁴⁴ Campbell and Reece, *Biology*, p. 632.

⁴⁵ “Two Trials Show Stem-Cell Therapy Benefits Heart-Attack Patients,” *Health Day News*, 20 September 2006. Accessed: http://www.nlm.nih.gov/medlineplus/news/fullstory_38919.html

stop stem cell research. Rather, it should stimulate more basic stem cell research so that it can be used as treatment for sick people in the future. Dr. Anthony Rosenzweig, the director of cardiovascular research at Beth Israel Deaconess Medical Center in Boston, stated that “We should guard against both premature declarations of victory and premature abandonment of a promising therapeutic strategy.”⁴⁶ It is evident that current stem cell research is not ready to be used consistently in a clinical setting to treat actual patients. However, without further study, already promising results of studies using stem cells to treat damage and disease will not be explored, and potential life-saving therapies will not have a chance to be developed.

Besides moral and ethical objections to stem cell research, as well as objections to the potential harm stem cells may cause in recipient patients, over-expectations concerning stem cells and their possibilities may actually hinder the development of cures for diseases. As further advances are made, the expectation that stem cell research will be the complete “means” to solve all health issues could easily develop. This expectation may result in a complete focusing on stem cells with the exclusion of all other forms of therapeutic research because they may not hold as much promise as stem cells. However, this oversight will limit the disease and virus fighting arsenal that scientists are attempting to create as other forms of treatments also have the potential to effectively combat disease in different ways if further developed.

Gene therapy is one such form of therapeutic research that has the potential to combat disease. Gene therapy “encompasses a wide range of treatment types that all use

⁴⁶ Dr. Anthony Rosenzweig, *New England Journal of Medicine* (September 21, 2006), quoted in “Two Trials Show Stem-Cell Therapy Benefits Heart-Attack Patients,” *Health Day News*, 20 September 2006. Accessed: http://www.nlm.nih.gov/medlineplus/news/fullstory_38919.html

genetic material to modify cells (either *in vitro* or *in vivo*) to help effect a cure.”⁴⁷ In other words, by transferring a gene or specific sequence of DNA with a specific function into cells either in a Petri dish or in the body, those cells will then have the ability to fix a genetic defect or treat and/or cure a disease. Gene therapy is composed of many different treatment procedures which add specific genes or DNA to cells in the body in order to fix a defect or fight a disease. Two different treatment methods of gene therapy are gene transfer and immunotherapy.

Gene transfer encompasses taking a gene or section of DNA from one cell and transferring that gene or section of DNA into cells in the human body to fight and/or cure a disease. Specifically, gene transfer is “the introduction of specific nucleic acid sequences into selected target cells for the treatment or prevention of disease.”⁴⁸ One of the most common ways to insert new genetic material into cells in the body is through using viral vectors. Viral vectors are formed by modifying the genetic make-up of the virus so it cannot successfully replicate.⁴⁹ The desired sequence of DNA is then placed in the modified viral DNA, and the virus is introduced into the body. The virus attaches to the cell membrane of target cells through recognition of specific receptors on the cell surface and injects the modified DNA into the cell. The cell then replicates the desired DNA sequence to fight the disease, similar to how the virus normally replicates.⁵⁰

Gene transfer, as well as other gene therapy techniques, have been used as potential cures for diseases, including Duchene Muscular Dystrophy and certain

⁴⁷ Deanna Cross, PhD and James K. Burmester, PhD, “Gene Therapy for Cancer Treatment: Past, Present, and Future,” *Clinical Medicine & Research* 4, no. 3 (2006): p. 218.

⁴⁸ Hillel Haim and Israel Steiner, “Gene Therapy to the Nervous System,” in *Stem Cell and Gene-Based Therapy: Frontiers in Regenerative Medicine*, (London: Springer-Verlag, 2006), p. 133.

⁴⁹ *Ibid.*, p. 135.

⁵⁰ Campbell and Reece, *Biology*, pp. 330-331.

cancers.^{51,52} However, current precautions and potential problems with gene transfer and gene therapy overall show that gene therapy as a whole is still in its developmental stages. Viruses in high doses can be very toxic and can also cause an immune response to the virus which could harm fully functional cells and tissues,⁵³ as an immune response may destroy fully functional cells in the body. There is also the possibility that the therapeutic gene will be introduced into “unwanted cell types, such as reproductive tissues.”⁵⁴ This could have adverse effects on any offspring because insertion of a gene into a fully normal egg or sperm gene may result in birth defects of a child born with two copies of a gene when only one is needed. The inserted gene could also cause cancer if a disruption of normal, regulatory gene function occurs.^{55,56} Because of these reasons, gene transfer and gene therapy as a whole currently only has the potential to treat disease, as more research needs to be conducted before it can be used as a widespread clinical treatment.

Immunotherapy is another developing gene therapy technique with the potential to combat disease, especially cancer. Immunotherapy is the “boosting of the immune system to target and destroy cancer cells.”⁵⁷ This can be accomplished by introducing specific antibodies into the body, which will either bind to receptors on cancer cells, marking the cells for destruction by the immune system, or bind to receptors that will

⁵¹ Guang-qian Zhou, Hui-qi Xie, Su-zhen Zhang, and Zhi-ming Yang, “Current understanding of dystrophin-related muscular dystrophy and therapeutic challenges ahead” *Chinese Medical Journal* 119, no. 16 (2006): p.1385.

⁵² Cross and Burmester, *Clinical Medicine & Research*, p. 223.

⁵³ Siddhesh D. Patil, David G. Rhodes, and Diane J. Burgess, “DNA-based Therapeutics and DNA Delivery Systems: A Comprehensive Review,” *The AAPS Journal* 7 (2005), p. E69.

⁵⁴ Cross and Burmester, *Clinical Medicine & Research*, p. 223.

⁵⁵ Patil, Rhodes and Burgess, *The AAPS Journal*, p. E69.

⁵⁶ Cross and Burmester, *Clinical Medicine & Research*, p. 223.

⁵⁷ *Ibid.*, 219.

signal the cells to either stop dividing or undergo apoptosis,⁵⁸ or programmed cell death.⁵⁹ Through immunotherapy, cancer vaccines, whose purpose is to present antigens or cancer cell debris to the immune system in order to initiate an immune response against the cancer cells, have also been developed.⁶⁰ These cancer vaccines contain parts of the active cancer cell, but not enough of the cell to cause cancer. However, the immune cells in the body will recognize these cancer cell pieces, or antigens, as foreign, and will consequently attack and destroy the cancer cells.

Immunotherapy to date has only had limited success in the fight against diseases such as cancer. Cancer cells are effective in evading immune detection.⁶¹ A successful immune response to introduced antigens and cancer vaccines can currently only be maintained for a limited period of time.⁶² This shows that while immunotherapy has the potential to fight and/or cure diseases such as cancer, much more research needs to be conducted to achieve success.

Besides developing gene therapy techniques as possible methods to fight disease and replace damaged genes, using molecular targeting of therapeutic drugs is also being developed as a potential treatment for disease. These therapeutic drugs are targeted to specific cells by being attached to molecules that bind to certain receptors. Once bound to the receptor, the drug would cause repression of specific genes or promote cell death. Michael Sporn described chemoprevention, a form of molecular targeting of therapeutic

⁵⁸ Cancer Research Institute, "Cancer and the Immune System: The Vital Connection, Chapter 5.1," n.d., <http://www.cancerresearch.org/immunology/advancesimm.html> (11 November 2006).

⁵⁹ Campbell and Reece, *Biology*, p. 420.

⁶⁰ Cross and Burmester, *Clinical Medicine & Research*, pp. 219-220.

⁶¹ *Ibid.*, 219.

⁶² *Ibid.*, 220.

drugs, as using chemical substances to prevent, stop, or reverse a disease.⁶³ This means that by targeting certain chemical molecules to cells, the chemical substance will either prevent the cells from becoming diseased, for example, becoming malignant, or stopping the growth of the disease. Immunotoxins, which are “protein toxins connected to a cell binding ligand of immuno logic interest,”⁶⁴ are also used as a therapeutic drug that is targeted to specific cells. In other words, certain protein toxins are linked to an antibody which binds to a specific receptor on specific cells. Once bound, the protein can enter the cell and through enzymatic activity, cause the cell to die.⁶⁵ This would allow only specific cells, targeted by the specific antibody, to be affected by the deadly protein, leaving healthy cells untouched and unharmed.

While this research is very promising, many genes and receptors are found in normal cells as well as diseased cells, making targeting of diseased cells currently difficult. Toxicity levels caused by immunotoxins may also be deadly in higher doses, which may limit the effectiveness of these drugs. While some drugs and chemical molecules are currently being used to fight disease, especially in cancer, more research needs to be conducted before the molecular targeting of therapeutic drugs is used widely in the clinical setting.

It is evident that a complete focusing in stem cell research and excluding other forms of research and potential therapies would be detrimental to the development of treatments for many diseases because other treatments show great promise. However, the fact that there are still many issues with alternative treatment methods shows that stem

⁶³ Rajesh L. Thangapazham, Anuj Sharma, and Radha K. Maheshwari, “Multiple Molecular Targets in Cancer Chemoprevention by Curcumin,” *The AAPS Journal* 8 (2006), p. E443.

⁶⁴ Robert J. Kreitman, “Immunotoxins for Targeted Cancer Therapy,” *The AAPS Journal* 8 (2006), p. E532.

⁶⁵ *Ibid.*

cell research does need to continue because of its potential to fight and/or cure many diseases. Stem cells may also be used in combination with other developing treatments to make them safer to use. For example, gene transfer could be done in stem cell cultures outside of the body. Because stem cells replicate countless times, those stem cells that exhibited “safe and effective integrations”⁶⁶ of the transferred gene could then be further replicated and introduced into the body. Therefore, “the transfer of a therapeutic gene to stem cells has the potential to provide long-lasting correction of a number of acquired or inherited disorders.”⁶⁷ Stem cells in culture may also be pushed to differentiate into T cells that recognize certain cancer cell surface markers. If injected into the body, these T cells would then be able to target and destroy cancer cells.

Consequently, while stem cell research should not be seen as the “cure-all” for every disease, neither should stem cell research be stopped in favor of other forms of research for potential treatments of disease. Currently, every form of potential treatment, including stem cells, has positives as well as negatives that need to be addressed before the treatment can be widely used and determined successful or not. Zhou *et al.*, state that “It is most likely that only a combination of multiple approaches will eventually lead to the development of treatments.”⁶⁸ Therefore, as long as stem cell research does not become the only solution for the development of treatments and all avenues of medical research are explored and developed, the consequences brought about by a sole focus on stem cell research can be avoided.

⁶⁶ Matthew H. Porteus, Jon P. Connelly, and Shondra M. Pruett, “A Look to Future Directions in Gene Therapy Research for Monogenic Diseases,” *PLoS Genetics* 2, no. 9 (2006): p. 1291.

⁶⁷ Ilaria Bellantuono and Leslie J. Fairbairn, “Adult Stem Cells and Gene Therapy,” in *Tissue Stem Cells* (New York: Taylor & Francis Group, 2006), p. 305.

⁶⁸ Zhou, Xie, Zhang, and Yang, *Chinese Medical Journal*, p.1388.

While there are negatives to stem cell research, each, when fully examined, can be overcome or compensated for. Some of the controversy of stem cell research will always be present, no matter what is done. However, it is evident that as stem cell research continues to demonstrate the many potential strengths of stem cells, they will become an even more important factor in the discovery of new treatments for the many health issues that plague people today. If the advantages of stem cells are capable of outweighing the risks examined above, there should be, as a result, substantial support for the continuation of stem cell research, an increase in federal funding, and a loosening of restrictions on stem cell research.

Advantages and Benefits of Stem Cell Research

The potential negatives associated with stem cell research should prompt people to move carefully as more is discovered about stem cells and an increase in clinical trials for stem cell therapies are conducted. It is imperative that stem cell research for all types of stem cells not only continues, but continues to grow and develop as time passes, for stem cell research has the ability to change the future of medicine and research. “Stem cell research holds much promise: *in vitro* work will provide insights into disease mechanisms, and one day there will be new treatments for intractable congenital and chronic diseases.”⁶⁹ Each broad type of stem cells has many potential benefits that are waiting to be discovered, expanded, and perfected to help people live a better quality of life.

While each broad type of stem cell has many potential benefits, some which are in the process of being achieved already, there are obvious differences that currently make

⁶⁹ The Lancet, “Stem cell research: hope and hype,” *The Lancet* 365, issue 9475 (2005): p. 1904.

embryonic stem cells the most useful type of stem cell for experimentation and possible treatments. Currently, embryonic stem cells have a greater research and medical potential than the non-embryonic adult and cord blood stem cells. Embryonic stem cells have great potential because they have certain qualities that non-embryonic stem cells do not possess. These qualities allow embryonic stem cells to be more versatile and give researchers the necessary tools to study every type of cell in the body and how development occurs in the hope of finding cures to every known disease and defect.

The most obvious difference between embryonic stem cells and adult and umbilical cord blood stem cells is that embryonic stem cells can differentiate into all three germ layers of the embryo: ectoderm, mesoderm, and endoderm, while adult and umbilical cord blood stem cells are usually committed to one layer.^{70,71} In other words, embryonic stem cells have the potential to become any cell in the body and form any tissue while adult and umbilical cord blood stem cells are restricted in cell fate to only have the potential to become cells from the specific tissue they originated in or into cells that are similar to the original tissue.^{72,73} This means that embryonic stem cells provide researchers with a “blank slate” that they can use to study any cell, function, or process that is found in the human body. Non-embryonic stem cells do not appear to have the ability to provide researchers with this “blank slate.” Because of this fact, embryonic stem cells can be used to conduct research on any cell type to discover treatments for almost any disease, whereas adult and umbilical cord blood stem cells may only be used

⁷⁰ Bernard E. Tuch, “Stem cells: A clinical update,” *Australian Family Physician* 35, no. 9 (2006): p. 721.

⁷¹ George Q. Daley, Margaret A. Goodell, and Evan Y. Snyder, “Realistic Prospects for Stem Cell Therapeutics,” *The American Society of Hematology Education Program* (2003), p. 399.

⁷² Daley, Goodell, and Snyder, *The American Society of Hematology*, p. 402.

⁷³ Vincenzo Pirrotta and Maarten van Lohuizen, “Differentiation and gene regulation: Genomic programs and differentiation,” *Current Opinion in Genetics & Development* 16 (2006), p. 444.

to conduct research on specific cell or tissue types because they are pre-programmed to become a specific cell type.

Embryonic stem cells also have the ability to replicate indefinitely, providing an unlimited supply of stem cells to be used for research.⁷⁴ This means that embryonic stem cells can self-renew their own population of cells while also creating cells that can differentiate into any cell in the body. This feature of embryonic stem cells gives researchers the ability to conduct numerous experiments without having to find another source of stem cells. Non-embryonic stem cells do not have the same capability. Most non-embryonic stem cells have a limited life span in which accurate self-renewal occurs to produce more stem cells and cells that differentiate into specific cell types.⁷⁵ This means that non-embryonic stem cells can only replicate to produce more of the same stem cells for a limited time before they cannot replicate anymore or before they no longer replicate exact copies of themselves. Because of this, embryonic stem cells provide researchers with a nearly never-ending supply of stem cells in which to conduct research, which will result in more efficient experimentation and a greater amount of experimentation. Treatments and cures for various diseases may be found faster through the use of embryonic stem cells.

Immune rejection is always an issue when placing cells or tissues from one person into another. Foreign cells or tissues must have a close genetic match to the cells or tissues of the recipient. For example, in kidney transplants, the donor kidney must have similar genetic features and molecular markers in order for the recipient's immune

⁷⁴ Miodrag Stojkovic, Majlinda Lako, Tom Strachan, and Alison Murdoch, "Derivation, growth, and applications of human embryonic stem cells," *Reproduction* 128 (2004), p. 259.

⁷⁵ Darwin J. Prockop, MD, PhD, "Embryonic Stem Cells Versus Adults Stem Cells: Some Seemingly Simple Questions," in *Essentials of Stem Cell Biology* (California: Elsevier Academic Press, 2006), p. xxiii.

system to recognize the transplanted kidney as “self.” If non-embryonic stem cells are placed back into the individual they were already taken from, immune rejection is almost non-existent. However, it is not currently feasible that stem cell treatments only use a patient’s original stem cells to treat a disease or problem. If non-embryonic stem cells are transplanted into another patient, the host body will most likely identify the cells as “non-self” and will destroy them. It has been shown, however, that this immune rejection may not occur or may be much less if embryonic stem cells are used to treat individuals that the stem cells have not originated from. A recent set of experiments showed that both undifferentiated and differentiated embryonic stem cells that were transplanted in mice only elicited a minute immune response to the transplanted cells.⁷⁶ However, when mice were transplanted with adult stem cells, the transplanted cells were destroyed by the mouse host’s immune system. Researchers may also be able to genetically modify embryonic stem cells that so they express factors that immune-privileged cells in the body express to reduce the possibility of immune rejection during transplantation.⁷⁷ If immune rejection can be limited or eliminated for embryonic stem cell transplantation, then embryonic stem cells may be used for organ and tissue donations as well as for treating various diseases and problems in the body.

Embryonic stem cells have been used in many different types of experiments and there is much promise in what embryonic stem cells may be used for in order to treat patients. Besides the many aspects of embryonic stem cells that make them more useful

⁷⁶ M. Drukker, H. Katchman, G. Katz, S. Even-Tov Friedman, E. Shezen, E. Hornstein, O. Mandelboim, Y. Reisner, and N. Benvenisty, “Human embryonic stem cells and their differentiated derivatives are less susceptible to immune rejection than adult cells,” *Stem Cells* 24, no. 2 (2006): p. 221.

⁷⁷ Helen Priddle, D. Rohdri E. Jones, Paul W. Burridge, and Rodger Patient, “Hematopoiesis from Human Embryonic Stem Cells: Overcoming the Immune Barrier in Stem Cell Therapies,” *Stem Cells* 24 (2006), p. 816.

in research than non-embryonic stem cells, embryonic stem cells also have many potential and actual clinical applications that can help restore organ function. The restoration of tissue and organ function is very important medically because there are many individuals currently on wait lists for organ and tissue transplantation. These individuals have no guarantee they will receive the organ or tissue they need in time because there is such a shortage of organ and tissue donors. There is also the risk of immune rejection of the donated organ or tissue, which could result in the death of the individual. Therefore, developing treatments that use embryonic stem cells to regenerate organs and tissues and help to restore their function would potentially save countless lives.

One example of using embryonic stem cells to restore organ and tissue function is with damaged cardiac muscle that cannot efficiently beat or cannot beat at all. Scientists have been able to differentiate embryonic stem cells into functional cardiomyocytes, which are heart muscle cells that can be placed into the heart and help improve heart function. Cardiomyocytes developed from embryonic stem cells were placed in non-beating ventricle heart tissue in Petri dishes. The cardiomyocytes were shown to integrate into the host tissue and generate rhythmic signals that caused the whole tissue to begin to beat.⁷⁸ They also showed that when the transplanted embryonic-stem cell-derived cardiomyocytes were destroyed, the beating of the tissue stopped, which further suggests that the stem cells restored rhythmic function of cardiac tissue.⁷⁹ Further transplantation of these cells into cardiac muscle in the body also showed that these cells caused the heart

⁷⁸ Tian Xue, Hee cheol Cho, Fadi B. Akar, Suk-Ying Tsang, Steven P. Jones, Eduardo Marban, bordon F. Tomaselli and Ronald A. Li, "Functional Integration of Electrically Active Cardiac Derivatives from Genetically Engineered Human Embryonic Stem Cells with Quiescent Recipient Ventricular Cardiomyocytes: Insights Into the Development of Cell-Based Pacemakers," *Circulation* 111 (2005), p. 14.

⁷⁹ *Ibid.*, p. 15.

to beat. Developing cardiac cells that can control the heart beat of the heart is important because they could be used to help the pacemaker of the heart function correctly. This way, patients with irregular beating hearts or other cardiac issues will not need a mechanical pacemaker to help the heart beat correctly. This experiment demonstrates that embryonic stem cells can potentially be used to restore the function of damaged tissues or organs.

The Nervous System is also another target for using embryonic stem cells to restore function since it is believe that the Nervous System cannot easily repair itself once damaged. When a spinal cord is injured, loss of function often occurs because the myelin sheath that covers the axons of neurons is destroyed and cannot re-grow. The myelin sheath is very important in the transport of messages through the nervous system because it allows for signals to be relayed very rapidly throughout the body. Embryonic stem cells were recently differentiated into oligodendrocyte progenitor cells, which is the pre-cursor form of the neural cells that produce myelin.⁸⁰ These oligodendrocyte progenitor cells were then transplanted into rats that had suffered spinal cord injuries. In rats that had recently suffered spinal cord injuries, the oligodendrocytes became functionally integrated into the site of injury and remyelinated neuron axons. This remyelination caused a recovery of motor function in the rats,⁸¹ showing that embryonic stem cells can be used to help regenerate and restore the function of damaged neural tissue. Scientists hope that one day, oligodendrocytes formed from human embryonic stem cells will be

⁸⁰ Hans S. Keirstead, Gabriel Nistor, Giovanna Bernal, Minodora Totoiu, Frank Cloutier, Kelly Sharp, and Oswald Steward, "Human Embryonic Stem Cell-Derived Oligodendrocyte Progenitor Cell Transplants Remyelinate and Restore Locomotion after Spinal Cord Injury," *The Journal of Neuroscience* 25, no. 19 (2005): p. 4694.

⁸¹ *Ibid.*

transplanted into patients with spinal cord injuries to help them recover their ability to move.

It is evident then that embryonic stem cells can be used to regenerate cells in tissue and to help restore the function of tissue and/or organs in the body. Embryonic stem cells have also been shown to have the potential ability to reduce the symptoms of diseases or help cure those diseases. Many diseases today are currently incurable. However, even if a cure cannot be found, the ability to treat the disease and lessen the symptoms of the disease will at the least allow individuals to live a longer, better quality of life than if there was no treatment for the disease.

Neural diseases are very attractive diseases to use embryonic stem cells to combat because they are so devastating to those who suffer from them. Embryonic stem cells can form different types of neural cells in vitro, and have recently been used in trials to treat certain neural diseases, such as Parkinson's disease. Parkinson's disease is "a neurodegenerative disorder that is characterized by" the loss of dopamine-producing neurons and lower dopamine levels in the brain.⁸² The loss of these neurons causes a decrease in function of the brain. Recently, monkey embryonic stem cells were differentiated into neural progenitors, which then differentiated into neurons that produced dopamine.⁸³ These dopamine-producing neurons were then transplanted into the brain of a monkey model of Parkinson's disease. The transplanted cells integrated functionally into the brain and functioned as dopamine-producing cells, which reduced

⁸² Yasushi Takagi, Jun Takahashi, Hidemoto Saiki, Asuka Morizane, Takuya Hayashi, Yo Kishi, Hitoshi Fukuda, Yo Okamoto, Masaomi Koyanagi, Makoto Ideguchi, Hideki Hayashi, Takayuki Imazato, Hiroshi Kawasaki, Hirofumi Suemori, Shigeki Omachi, Hidehiko Iida, Nobuyuki Itoh, Norio Nakatsuji, Yoshiki Sasai, and Nobuo Hashimoto, "Dopaminergic neurons generated from monkey embryonic stem cells function in a Parkinson primate model," *Journal of Clinical Investigation* 115 (2005), p. 102.

⁸³ *Ibid.*

the symptoms of Parkinson's disease in the monkey.⁸⁴ This research is monumental because it shows that embryonic stem cells can be used to create neurons that help relieve the symptoms of a currently incurable disease. Future steps will take this technology and use it to see if human embryonic stem cells can form dopamine-producing neurons and function as such in the brain of people with Parkinson's. This shows that it is conceivably possible to help relieve the symptoms of Parkinson's disease in the near future, and further research will open the door to discovering a cure for the disease.

Different platelet dysfunctions are another form of disease that can be very deadly and devastating to those who suffer from it. Platelets are important factors that help in the blood clotting process. With non-functional platelets, any significant "bump" or tissue damage could cause internal bleeding that could lead to the death of the individual. It has been shown that mouse embryonic stem cells can differentiate into mature megakaryocytes, which are a type of cell found in the blood.⁸⁵ These mature megakaryocytes were then able to produce functional platelets. When these platelets were stimulated, as would occur during tissue damage, they aggregated together and formed stress fibers as normal platelets would.⁸⁶ By being able to differentiate embryonic stem cells into megakaryocytes that produced functional platelets, individuals with bleeding disorders and other platelet dysfunctions may be cured and would be able to live life normally. As research continues, human embryonic stem cells will be differentiated into megakaryocytes that can produce functional platelets to be used in transplants and for individuals who suffer from platelet dysfunctions.

⁸⁴ Takagi *et. al.*, *Journal of Clinical Investigation*, p. 102..

⁸⁵ Tetsuro-Takahiro Fujimoto, Satoshi Kohata, Hidenori Suzuki, Hiroshi Miyazaki, and Kingo Fujimura, "Production of functional platelets by differentiated embryonic stem cells in vitro," *Blood* 102, no. 12 (2003): p. 4044.

⁸⁶ *Ibid.*, 4049.

Diabetes is a disease that affects millions of people worldwide and can have devastating effects on the life and happiness of those with the disease. With one form of diabetes, the cells in the pancreas that produce insulin are destroyed. Without insulin, glucose levels in the body cannot be regulated, and the body cannot maintain homeostasis. Human embryonic stem cells have recently been differentiated into insulin containing cells.⁸⁷ These cells cannot produce insulin by themselves, but when transplanted with mouse embryonic pancreas into host mice, the cells produced human insulin.⁸⁸ This suggests that there are specific factors that are necessary to transform the insulin containing cells into the cells that actually produce the insulin in the pancreas. This data suggests that once the specific factors that cause the insulin containing cells that differentiated from human embryonic stem cells to become actual insulin producing cells, these cells could be put into individuals who suffer from Type I diabetes. It is evident then that embryonic stem cells can become insulin containing cells, and that as research continues and more is discovered as to how these cells become insulin producing cells and how pancreatic tissue can be regenerated, embryonic stem cells will become a viable treatment for people who suffer from diabetes.

Embryonic stem cells are also currently being used in numerous other experiments to discover treatments and cures for diseases and to help regenerate tissues and organs and improve their function. Mouse embryonic stem cells can differentiate into osteoblasts which can produce bone tissue both in vitro and in vivo.⁸⁹ This is

⁸⁷ Gabriella K.C. Brolen, Nico Heins, Josefina Edsbacke, and Henrik Semb, "Signals From the Embryonic Mouse Pancreas Induce Differentiation of Human Embryonic Stem Cells Into Insulin-Producing β -Cell-Like Cells," *Diabetes* 54 (2005), p. 2867.

⁸⁸ *Ibid.*, p. 2868.

⁸⁹ RC Bielby, AR Boccaccini, JM Polak, and LD Buttery, "In vitro differentiation and in vivo mineralization of osteogenic cells derived from human embryonic stem cells," *Tissue Eng.* 10 (2004), p. 1518.

significant because using this technology to differentiate human embryonic stem cells into osteoblasts, which could then be used to form bone for individuals with birth defects that result in incorrect bone formation as well as a treatment for osteoporosis. A biological solution containing stem cells was injected into the paralyzed left arm and leg of a man who suffered a stroke. He has regained some of the mobility in the affected limbs as a result of the treatments.⁹⁰ Embryonic stem cells may also be used to introduce the correct gene into muscle tissue to help individuals who suffer from muscular dystrophy.⁹¹ Current cancer therapy experiments are also utilizing the diverse properties of embryonic stem cells to try to find treatments and/or cures for different types of cancer.⁹² It is evident then that the uses for embryonic stem cells in the developments of disease treatments and the regeneration of tissues and organs are very diverse. Each different use of embryonic stem cells illustrates its importance to the development of treatments and cures.

Embryonic stem cells are also being used to fight viruses that cause disease as well as testing new drugs for their effectiveness on the target tissue. Embryonic stem cells have recently been differentiated into mature T-cells that can fight disease and possibly combat AIDS.⁹³ Embryonic stem cells have also recently been differentiated into cells that can be infected with the HIV virus.⁹⁴ These cells are then genetically altered to express anti-HIV genes, and are then tested to determine their effectiveness at

⁹⁰ "Stem Cell Therapy International Announces the Successful Treatment of Stroke Victim Who Received Stem Cell Transplantation Therapy," *Market Wire News*, 27 October 2005.

Accessed: http://www.marketwire.com/mw/release_html_b1?release_id=99398

⁹¹ Zhou, Xie, Zhang, and Yang, *Chinese Medical Journal*, p. 1386.

⁹² Mimeault and Batra, *Stem Cells*, p. 29.

⁹³ Robert Preidt, "Scientists Turn Stem Cells into Disease-Fighting T-Cells," *HealthDay News*, 4 July 2006. Accessed: http://www.nlm.nih.gov/medlineplus/news/fullstory_35649.html

⁹⁴ Joseph S. Anderson, Sriram Bandi, Dan S. Kaufman, and Ramesh Akkina, "Derivation of normal macrophages from human embryonic stem cells for applications in HIV gene therapy," *Retrovirology* 3, no. 24 (19 April 2006): p. abstract.

producing cells that can fight the HIV virus.⁹⁵ This is significant because if cells can be developed that can fight HIV, precursors of these cells can be introduced into the body. Once in the body, these cells can divide and increase in number, providing the body with a mechanism to quickly fight HIV.

Because embryonic stem cells can develop into any cell or tissue in the body, they are also excellent sources in which to test the toxicity of new drugs. Embryonic stem cells can be used to create a specific target tissue for a new drug.⁹⁶ The tissue would then be treated to determine the drug's effects on the target tissue. This way, new therapeutic drugs can be tested before they ever show up in clinical trials, reducing the potential for damage done by the therapeutic drug in later clinical trial tests.⁹⁷ These other uses for embryonic stem cells further demonstrate the many capabilities of embryonic stem cells and the significant role they play in drug development, disease treatment, and finding cures for diseases. It is evident that embryonic stem cells have the potential to provide many benefits that significantly outweigh any potential negatives that surround embryonic stem cell research.

Although it is quite evident that embryonic stem cells hold the most potential for research and medical applications in the near future, non-embryonic stem cell sources such as adult stem cells and umbilical cord blood stem cells should not be ignored; rather, they should also be widely researched because they do carry medical potential and are currently being used in certain clinical treatments. Adult stem cells are readily found in the bone marrow and blood as hematopoietic and non-hematopoietic stem cells, and can

⁹⁵Anderson, Bandi, Kaufman, and Akkina, *Retrovirology*, p. abstract.

⁹⁶Julio C. Davila, Gabriela B. Cezar, Mark Thiede, Stephen Strom, Toshio Miki, and James Trosko, "Use and Application of Stem Cells in Toxicology," *Toxicological Sciences* 79. no. 2 (2004): pp. 215-216.

⁹⁷*Ibid.*

also be found in neural tissue as neural stem cells, skeletal muscle as satellite cells, liver tissue,⁹⁸ adipose tissue as mesenchymal stem cells,⁹⁹ and in other adult tissues. Bone marrow and blood stem cells can differentiate into blood lineage cells as well as muscle cells, neurons, liver cells, adipose cells, and osteoblasts.¹⁰⁰ This makes bone marrow and blood stem cells very useful in running experiments because they can become a number of different cell types, allowing for different kinds of research to be conducted from one type of cell.

Adult stem cells do have the potential to be used in certain medical treatments in the future as they do have some varied differentiation capability. They also can be used to treat patients that the adult stem cells were taken from in order to decrease the likelihood of immune rejection of the transplanted cells. For example, mesenchymal stem cells found in adipose tissue in adults has recently been shown to be able to form cartilage *in vivo*.¹⁰¹ The stem cells were treated with factors that pushed them toward a cartilage lineage, and then they were transplanted in mice. Definite cartilage formation was observed, and after 20 weeks, there was no decrease in the amount of cartilage present that was formed by the stem cells.¹⁰² The formation of cartilage from adult stem cells is important because the mesenchymal stem cells could one day be removed from an individual, induced to become cartilage cells, and placed back in the body to restore the cartilage of a knee or shoulder, eliminating the need for painful and risky surgery.

⁹⁸ Maciej Tarnowski and Aleksander L. Sieron, "Adult stem cells and their ability to differentiate," *Med. Sci. Monit.* 12, no. 8 (2006): pp. RA155-RA159.

⁹⁹ Yunfeng Lin, En Luo, Xizhe Chen, Lei Liu, Ju Qiao, Zhengbin Uan, Zhiyong Li, Wei Tang, Xiaohui Zheng, and Weidong Tian, "Molecular and Cellular characterization durin gchondrogenic differentiation of adipose tissue-derived stromal cells *in vitro* and cartilage formation *in vivo*," *Journal of Cellular and Molecular Medicine* 9, no. 4 (2005): p. 929.

¹⁰⁰ Tarnowski and Sieron, "Adult stem cells," *Med. Sci. Monit.* p. RA156.

¹⁰¹ Lin, Luo, Chen, Liu, Qiao, Uan, Li, Tang, Zheng, and Tian, *J. Cell. Mol.Med.*, p. 929.

¹⁰² *Ibid.*, pp. 933, 935-936.

Unlike adult stem cells, umbilical cord blood stem cells are only found in the umbilical cord blood of newborn babies. The stem cells found in umbilical cord blood are mainly hematopoietic stem cells, which can differentiate to produce cells of blood lineage. Umbilical cord blood stem cells are an alternative source of hematopoietic stem cells and are increasingly used for hematopoietic stem cell transplantations, which can save the lives of those individuals with blood malignancies, bone marrow failure, and hereditary immunodeficiency disorders.¹⁰³ Umbilical cord blood stem cells are beneficial because procuring the stem cells has no risk to the donor, there is less of a viral contamination, less of a chance for immune rejection, and can easily be obtained.^{104,105} This makes umbilical cord blood a good source of stem cells that will form cells of blood lineage.

While umbilical cord blood stem cells can be pushed into different cell types, hepatocyte-like or liver-like cells,¹⁰⁶ cartilage,¹⁰⁷ and neural cells,¹⁰⁸ the biggest use of these stem cells is to treat people with deadly blood and bone marrow disorders. One of the most successful types of transplantation is in patients who suffer from Fanconi anemia. “Fanconi anemia is a rare autosomal recessive disease characterized by bone

¹⁰³ William Tse and Mary J. Laughlin, “Umbilical Cord Blood Transplantation: A New Alternative Option,” *Hematology* (2005), p. 377.

¹⁰⁴ *Ibid.*

¹⁰⁵ Tracey A O’Brien, Karin Tiedemann, and Marcus R. Vowels, “From Bench to Bedside: No longer a biological waste product: umbilical cord blood,” *MJA* 184, no. 8 (2006): p. 407.

¹⁰⁶ Amar Deep Sharma, Tobias Cantz, Rudolf Richter, Klaus Eckert, Reinhard Henschler, Ludwig Wilkens, Andrea Jochheim-Richter, Lubomir Arseniev, and Michael Ott, “Human Cord Blood Stem Cells Generate Human Cytokeratin 18-Negative Hepatocyte-Like Cells in Injured Mouse Liver,” *American Journal of Pathology* 167, no. 2 (2005): p. 555.

¹⁰⁷ Julie R. Fuchs, Didier Hannouche, Shinichi Terada, Sarvenaz Zand, Joseph P. Vacanti, and Dario O. Fauza, “Cartilage Engineering from Ovine Umbilical Cord Blood Mesenchymal Progenitor Cells,” *Stem Cells* 23 (2005), p. 958.

¹⁰⁸ Ning Chen, Jennifer E. Hudson, Piotr Walczak, Iwona Misiuta, Svitlana Barbuzova-Davis, Lixian Jiang, Juan Sanchez-Ramos, Paul R. Sanberg, Tanja Zigova, and Alison E. Willing, “Human Umbilical Cord Blood Progenitors: The Potential of these Hematopoietic Cells to Become Neural,” *Stem Cells* 23 (2005), p. 1560.

marrow failure, developmental anomalies, and a high incidence of myelodysplasia and acute myeloid leukemia.”¹⁰⁹ Autosomal recessive means that both parents would have to carry a gene for the disease, and that the child would receive both of those genes in order to have the disease. Bone marrow failure would cause problems in blood cell development, immune system development, and development of the bones. The first successful umbilical cord blood stem cell transplantation to cure Fanconi anemia occurred in 1988 for a 5 year old child by Gluckman and his colleagues.¹¹⁰ This was a significant achievement because before this time, the disease was incurable, and it remains incurable today except for umbilical cord blood stem cell transplants. The patient is still alive today, and thousands of cord blood stem cell transplants have been made throughout the world since then.¹¹¹ It is evident then that umbilical cord blood stem cells have great medical importance as they are already used to help those with deadly blood and bone disorders, and also show potential to form different cell types, allowing other forms of stem cell research to be conducted.

It is evident that all forms of stem cells hold great potential to change the way medicine treats disease and injury. Each type of stem cell has the potential to differentiate into more than one cell type, and in the case of embryonic stem cells, they have the potential to differentiate into any type of cell in the body. This gives researchers an advantage because they can discover how development and differentiation occurs in the

¹⁰⁹ Bella Dielorai, Mark R. Hughes, Arleen D. Auerbach, Arnon Nagler, Ron Loewenthal, Gideon Rechavi, and Amos Toren, “Successful umbilical cord blood transplantation for Fanconi anemia using preimplantation genetic diagnosis for HLA-matched donor,” *American Journal of Hematology* 77, no. 4 (2004): p. 397.

¹¹⁰ E. Gluckman, HA Broxmeyer, AD Auerbach, et al., “Hematopoietic reconstitution in a patient with Fanconi’s anemia by means of umbilical-cord blood from an HLA-identical sibling,” *N. Engl. J. Med.* 321 (1989), pp. 1174-1178, quoted in William Tse and Mary J. Laughlin, “Umbilical Cord Blood Transplantation: A New Alternative Option,” *Hematology* (2005), p. 377.

¹¹¹ Tse and Laughlin, “Umbilical Cord Blood Transplantation,” *Hematology*, p. 377.

hopes of correcting genetic defects before birth. Stem cells provide scientists with the ability to discover how cells and chemical factors and hormones can be used to regenerate injured or damaged muscle, helping many people who would die before receiving a life-saving transplant. Stem cells provide the ability to look at how different diseases develop and how viruses and bacteria cause disease in the effort to develop cells, drugs or other molecules to treat, fight and cure currently deadly and incurable diseases. Stem cells also provide the opportunity to test out new drugs to see their effect on target tissues before they are actually given to people. Each of these and many other potential abilities of stem cells all necessitate the continuation, growth, and development of stem cell research. Without the continued growth and development of stem cell research, many of these potential benefits may be achieved many decades from now or may never be achieved. Many of the benefits of stem cell research are only in the potential benefit stage at the present time. However, even the possibility of one day achieving those benefits outweighs the current negatives surrounding stem cell research and demands that changes be made in government to allow for stem cell research to grow.

Governmental Policy and Public View of Stem Cell Research in the United States

Current governmental policies in the United States regulate stem cell research and the funding available to specific cell lines. Since August of 2001, the Presidential policy concerning stem cell research and federal funding has placed restrictions on which stem cell lines may receive federal funding. The current federal policy states that as of August 9, 2001, federal funding would only be available to stem cell lines that were already in existence, that were derived from embryos originally created for reproductive purposes,

that were used for research with the consent of the donors, and that did not originate because the donors were offered financial gain.¹¹² When the policy was originally enacted, there were potentially 60 stem cell lines that qualified for federal funding.¹¹³ However, because many of the stem cell lines were difficult to grow, currently carry abnormalities or genetic mutations, or are unable to replicate anymore, there are only 21 lines that are currently eligible to receive federal funding.^{114,115} This means that for researchers who conduct research on federally-funded stem cell lines, there are not many lines to work with and the lines are no longer as viable or as plastic because they are old, carry mutations, and were grown using outdated techniques. Researchers are allowed to conduct research on non-federally funded stem cell lines; however, it is often difficult to receive enough private funds to conduct necessary experiments and purchase necessary equipment.

Besides limiting what stem cell lines can receive federal funding, current governmental policy has also limited what research can be done. As discussed earlier, all of the current stem cell lines that receive federal funding are grown and maintained on mouse-derived feeders. This immediately limits what types of therapeutic applications these stem cells can be utilized for, because of the risk of introducing foreign pathogens into the human body. However, with the development of feeders that are completely derived from human cells,¹¹⁶ these newly established stem cell lines can readily be used

¹¹² The President's Council on Bioethics, *The Administration's human Embryonic Stem Cell Research Funding Policy: Moral and Political Foundations*, September Council Meeting, 2003, p. 4. Accessed: http://bioethicsprint.bioethics.gov/background/es_moralfoundations.html

¹¹³ "Come Veto or High Water," *Nature* 442, no. 7101 (2006): p. 329.

¹¹⁴ *Ibid.*

¹¹⁵ Nancy Gibbs, Alice Park, and Dan Cray, "Stem Cells: The hope and the hype," *Time* 168, no. 6 (2006): p. 40.

¹¹⁶ Stojkovic, Lako, Stewart, Przyborski, Armstrong, Evans, Murdoch, Strachan, and Stojkovic, *Stem Cells*, p. 310.

in human clinical trials without the risk older stem cell lines carry. Without governmental funding to support these new lines, further development of these lines and medical applications using these new lines will be greatly inhibited.

Currently, about two-thirds of Americans support embryonic stem cell research.¹¹⁷ This widespread support for embryonic stem cell research was evident throughout the recent political campaigns surrounding the November 2006 elections. Numerous candidates openly supported stem cell research as part of their platform. The public, in general, also seemed to support those candidates in favor of embryonic stem cell research. Michael J. Fox, who has Parkinson's Disease, actively showed support for candidates who advocated for the continuation of embryonic stem cell studies. Many Americans today believe "it is more important to conduct stem cell research that may result in medical cures than to not destroy the potential life of human embryos."¹¹⁸ Therefore, if the majority of people support embryonic stem cell research, the federal government should undertake measures to reflect this sentiment. The governmental system is based on the fact that elected officials are supposed to make decisions based upon the wants and needs of the people they represent. This basic fundamental ideal of American government will not be upheld if current laws and policies are not changed to reflect the views of the American public.

In light of the fact that the majority of Americans support embryonic stem cell research, a bill was passed in both the Senate and the House of Representatives giving

¹¹⁷ "Come Veto or High Water," p. 329.

¹¹⁸ "GOP the Religion-Friendly Party, But Stem Cell Issue May Help Democrats," n.d., <<http://pewforum.org/docs/index.php?DocID=51>>

more funding to embryonic stem cell research.¹¹⁹ This increased federal funding would have allowed for the establishment of new, superior stem cell lines. These new lines would have been grown in completely human-derived cultures. The President vetoed that bill this past summer because he did not agree with using federal tax dollars to fund the destruction of human embryos.¹²⁰ However, the bill would still have required the destruction of embryos to be funded through private funds. Federal tax dollars would only have paid for *research* on the stem cell lines derived from the privately-funded destruction of embryos.¹²¹ In light of this fact, embryonic stem cell research, as well as other forms of stem cell research, have been further set back because the necessary funding to develop new and better stem cell lines was denied.

Current federal policy concerning stem cell research has provided over \$90 million for embryonic stem cell research since the original policy was enacted in August of 2001.¹²² While \$90 million may seem like significant amount of money, the federal government spends billions of tax dollars every year for other programs to better United States Society. The government sponsors vaccination programs, public health programs, nutritional education programs, and many other programs designed to better the health and wellness of America. In 2004, the government spent hundreds of millions of dollars on programs such as cancer prevention, diabetes control, immunization, and infectious diseases.¹²³ When compared to what is spent on other programs that develop drugs,

¹¹⁹ Meredith Wadman and Alison Abbott, "A long week in stem-cell politics...", *Nature* 442, no. 7101 (2006): p. 3335.

¹²⁰ "Come Veto or High Water," p. 329.

¹²¹ *Ibid.*

¹²² Office of Management and Budget, *Statement of Administration Policy: H.R. 810 – Stem Cell Research Enhancement Act* (Washington, D.C.: Management and Budget, 2006).

¹²³ Shelley A. Hearne, Kim Elliott, Chrissie Juliano, and Laura M. Segal, "Shortchanging America's Health: A state-by-state look at how federal public health dollars are spent," sponsored by Trust For America's Health, February 2005. p. 4. Accessed: www.healthyamericans.org

treatments for disease, and public health protection, it is evident that \$90 million dollars spent in five years on embryonic stem cell research is not enough federal funding to develop potential life-saving therapies.

Conclusions

There are some potential negatives to stem cell research, which mainly focus on embryonic stem cells. However, the countless possibilities of developing new drugs, new treatments, possible cures for diseases, and new weapons to fight deadly viruses outweigh any negatives that may arise from stem cell research. It is evident that the current federal policies and funding for embryonic stem cell research will not achieve the potential benefits of stem cells because stem cell lines are too old and mutated and there is not enough funding to run necessary experiments and develop better, safer techniques. The highly unequal distribution of federal funds for programs to better the health care of the American people further illustrates the lack of funding available for stem cells and developing stem cell therapies.

The recent veto has shown that the majority of the public and their governmental representatives support stem cell research. This support extends to the increase in funding and loosening of restrictions on stem cell research in order to develop cures and help people have a better quality of life. The overwhelming potential of stem cells and the promise they hold for the future of medicine and science show that in order for that potential to be achieved, federal funding needs to be increased and federal restrictions on what stem cell lines can be funded needs to be loosened. Only then will stem cells be able

to have the significant impact on and change how physicians will treat the injuries and diseases of their patients in the near future. “Stem cell research offers hope for people with a great diversity of illnesses, for people of all ages and genders and all backgrounds. It offers hope for each of us, and that hope is not measured in numbers. It is ultimately personal.”¹²⁴

¹²⁴ Mary Tyler Moore with S. Robert Levine, “It’s Not About Curiosity, It’s About Cures. Stem Cell Research: People Help Drive Progress,” in *Essentials of Stem Cell Biology* (California: Elsevier Academic Press, 2006), p. 514.

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