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STEM CELLS AND SOCIETY

An Interactive Qualifying Project Report

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WORCESTER POLYTECHNIC INSTITUTE

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Degree of Bachelor of Science

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ABSTRACT

This project investigated and described the impact of stem cells on society, as an example of the effects of technology on humanity. This objective was met by closely examining stem cells, describing their various types, methods of isolation, medical benefits, and the ethical and legal issues surrounding their use. Chapters 1 and 2 introduce stem cells and their use, while chapters 3 and 4 explore the ethical and legal issues with embryos and stem cell research. Based on the research performed in the project, the authors conclude that adult stem cells should be used in lieu of embryonic stem (ES) cells whenever possible, that excess embryos from IVF reproductive clinics should be used for ES cell research rather than embryos from paid donors, and that funding should be increased for stem cell research.

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PROJECT OBJECTIVES

The purpose of this project was to investigate the field of stem cell science, describing the various types of stem cells, their potential uses in the field of basic science and medicine, and describing their effects on society via their ethics and laws. Chapter-1 describes what stem cells are and their various types. Chapter-2 describes potential uses for stem cells in basic research and medicine, focusing on their benefit to mankind as a prelude to discussing their ethics. Chapter-3 discusses the ethical issues related to the use of these cells. Chapter-4 addresses the legal issues surrounding the use of stem cells and embryos in research, and discusses the laws that regulate scientists who work in the stem cell field. The project concludes with statements by the authors summarizing their own opinions on the controversial topic.

Chapter-1: Stem Cell Types and Sources

Ainaz Fathibitaraf

Stem cells are long lived cells with the ability to differentiate into various tissues. Because of this property, they form the basis of the new field of regenerative medicine, whose goal is to regenerate damaged or diseased tissues. But in spite of this amazing regenerative capacity and potential benefit to society, stem cells are also one of the most controversial topics in science today, surrounded by ethical and legal issues. The purpose of this chapter is to describe the various types of stem cells and their potencies, as a prelude to subsequent chapters on their applications, ethics, and laws.

Stem Cell Properties

All multi-cellular organisms contain a variety of cell types. These cells are all derived from a single cell, the zygote, through processes of differentiation and proliferation. The differentiation process involves the selective activation and inactivation of genes that dictate the properties of that cell. The newly fertilized egg divides for about 5-6 days until it forms a blastula or hollow ball of cells. The blastula consists of an inner cell mass (ICM) and an outer layer of cells. The inner cell mass is composed of embryonic stem (ES) cells, characterized by their undifferentiated state and their ability to divide for long periods of time. When stem cells divide, either the division is symmetric (both daughter cells remain as stem cells) or asymmetric (one of the daughter cells remains a stem cell and the other daughter differentiates into a more specialized cell) (USA.gov, 2009).

Stem cells retain the ability to develop into one or more cell types, depending on the type of stem cell (**Figure-1**). Stem cell populations differentiate into various types of cells such as

red blood cells, muscle cells, or nerve cells, and play a role in replacing the damaged cells in the living organism (Library of Congress, 2010). For example, skin stem cells are responsible for replacing the skin cells we are constantly losing, while muscle stem cells are involved in muscle repair and growth (Cordblood, 2011).

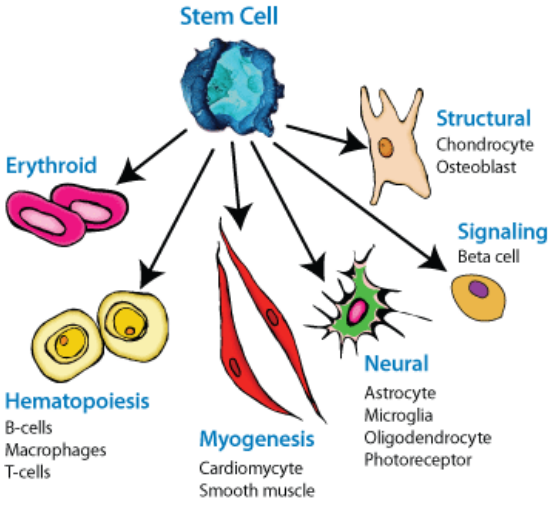

Figure-1: Stem Cell Differentiation. Stem cells are capable of division and renewal. They are unspecialized (un-differentiated) and have the ability to differentiate into specialized cells as shown in the figure. Embryonic stem cells are the most potent, and can differentiate into a variety of cell types including nerve, muscle, blood, and skin cells. (BioCat.com, 2011)

Stem Cell Discovery

The discovery of stem cells goes back to the 1800s when it was discovered that some cells have ability to produce other cells. During the 1900s, adult stem cells in bone marrow were first discovered. Doctors eventually used these to treat leukemia and anemia. The first bone marrow transplant on humans was a bone marrow transplant in 1957 (Thomas et al., 1957). Human embryonic stem cell lines were first established in 1998 by James Thomson and his colleagues from the University of Wisconsin (Thomson et al., 1998) (**Figure-2**). In this

experiment, Thompson isolated ES cells from the inner cell mass of blastulas, and grew them on a feeder layer of irradiated (killed) mouse fibroblast cells.

Figure-2: Photograph of James Thomson. Prof. Thomson is the American biologist who was the first to culture human embryonic stem cells from blastocyst embryos. (University of Wisconsin-Madison News, 2008)

Thomson's method of preparing ES cell lines from blastocysts has become far more popular than the second method performed by John Gearhart (**Figure-3**) from John Hopkins University, who was the first to culture human ES cells from fetal germline tissue, a far more controversial source of tissue than blastulas (All About Popular Issues, 2011).

Figure-3: Photo of John Gearhart. Shown is the American biologist who first grew human embryonic stem cells from fetal primordial germ cells. (Academy of Achievement, 2010)

As will be discussed in detail in Chapter-2, stem cells have been valuable as research and therapeutic tools. Researchers have been able to gain useful information concerning the signaling mechanisms involved in cell differentiation, and a better understanding of these processes will have great benefits in terms of cell-based therapies, which utilize stem cells to treat disease (USA.gov, 2009). Stem cells from bone marrow have been used for decades to treat leukemia and other blood-related diseases. In recent years stem cell therapy has been used to treat other conditions, including heart disease, lung cancer, and stroke (Malliaras et al., 2001; Bang et al., 2005; Weiss et al., 2008). Human stem cell experiments are based on animal models, such as mice, rats, and pigs. Although we are not yet at the stage where these treatments are widely available, it is likely that they will be in near future (USA.gov, 2009).

Stem Cell Classification

Stem cells are generally classified as either embryonic or adult (somatic). Embryonic stem cells (ESC) occur during the early stages of development, notably the inner cell mass of the blastocyst. During development, ESCs differentiate into all the various cell types found in an organism (**Figure-4**). The embryos used to isolate ES cells are obtained from excess *in vitro* fertilization (IVF) embryos originally created for reproductive purposes.

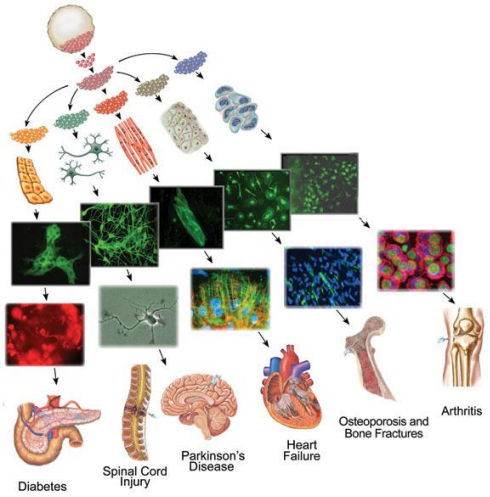

Figure-4: Differentiation of an Embryonic Stem Cell. ES cells are pluripotent, and can form all the types of cells in the adult body. (Everts, 2007)

Adult stem cells (ACS) have been isolated from a variety of adult tissues, including muscle, brain, bone marrow, skin, heart, and bone. These cells are responsible for maintaining the various tissues in the body. In general, ASCs are relatively rare cells within the adult tissues, and they are hard to isolate and grow (Garg, 2008). So some scientists prefer working with ES cells as they are relatively easy to isolate and grow. **Table-I** lists examples of ASCs and the cell types into which they differentiate. Adult stem cells, unlike ESC, are restricted in their potency, and can differentiate into fewer types of cells than ES cells. Although ASCs have significant drawbacks, their use does not destroy an embryo, so they have fewer ethical concerns. In addition, ASCs can be isolated from and used in the same individual, dramatically reducing the possibility of immune rejection (Garg, 2008).

Adult Stem Cell	Origin	Cell Types
Hematopoietic	Bone marrow	B-cells, T-cells, Macrophages
Neural	Nervous tissue	Astrocyte, Oligodendrocyte
Myogenesis	Muscle tissue	Cardiomyocyte, Smooth muscle
Cardiac	Bone marrow	Cardiac tissue
Mesenchymal	Bone marrow	Bone cartilage fat tendon muscle
Skin Cell	Epithelial cell	Skin

Table-I: Example of Various Adult Stem Cells and their Differentiation.

Another type of stem cell is the induced pluripotent stem (iPS) cell. These cells represent adult somatic cells, such as a skin fibroblast cell, reprogrammed into a pluripotent like state. Because no embryos are involved, and they appear to be pluripotent, scientists are excited about their possibly replacing ES cells in the future. A variety of somatic cells, including fibroblasts and neural stem cells, have been reprogrammed into de-differentiated embryonic-like stem cells by either transfecting specific genes into the cells or their proteins. The reprogramming is performed by transcription factors that help maintain the pluripotent like state.

iPS cells were discovered in Yamanaka's lab in Japan, and were first induced from mouse skin fibroblast cells (Takahishi et al., 2006) and then from human skin fibroblast cells (Takahashi et al., 2007). Initially, four transcription factor genes were used to perform the reprogramming: Oct3/4, Sox2, c-Myc, and Klf4. But later experiments indicated the presence of the c-Myc component induced tumor formation at the injection site, so that component was later omitted. Viruses were also used to deliver the genes, but due to worries about gene integration later experiments left out the viruses and just delivered the transcription factor proteins themselves. In the initial experiments to derive human iPS cells, the scientists reprogrammed fibroblasts from the facial skin of a 36 year old woman and from a 69 year old man (Takahashi et al., 2007).

These iPS cells have been a valuable advancement because of the relative ease of obtaining somatic cells and the elimination of the ethical issues surrounding embryo-derived ES cells. Scientists are still trying to prove exactly how potent these cells are, as some scientists claim the cells are more likely to have DNA mutations (Gore et al., 2011). Although the

techniques used to reprogram somatic cells are challenging, this technology hopefully will prove to be a great value to stem cell research.

Stem Cell Potencies

Stem cells are also commonly classified based on their potency, a measure of a stem cell's ability to differentiate into different cells (**Figure-5**). Cells capable of differentiating into all cell types, including the extra-embryonic tissues (e.g. placenta) of a developing organism are considered *totipotent*. The only cells with this level of potency are the zygote, or fertilized egg and cells through the eight-cell stage of development. The next level of potency, *pluripotent*, includes the ESCs mentioned earlier, which have the ability to differentiate into a wide variety of cell types of the body.

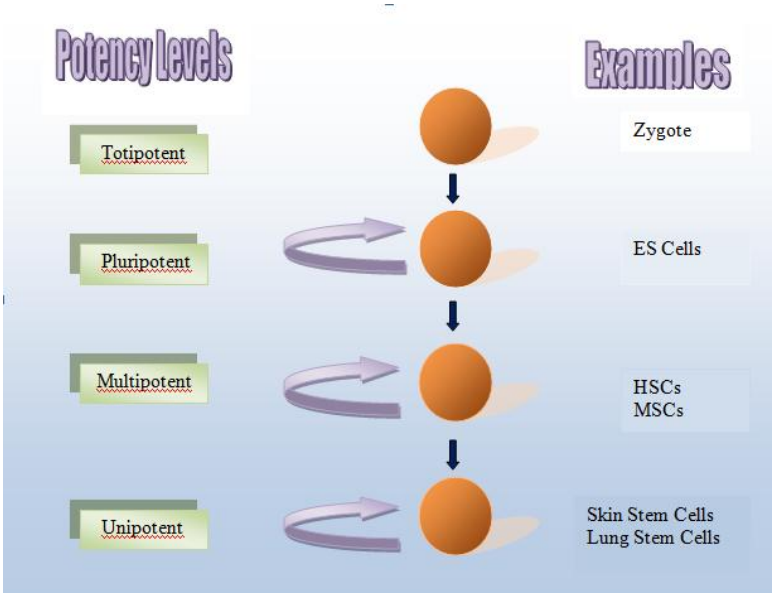

Figure-5: Diagram of the Major Categories of Stem Cell Potencies. *Totipotent* refers to a zygote through the 8-cell stage. Pluripotent cells are derived from the blastocyst and are exemplified by embryonic stem cells. Multipotent and unipotent cells have a more limited capacity to differentiate. Curved arrows indicate the ability of the cells to perpetuate.

Cells considered lower than pluripotent but higher than multipotent are the three primary germ layers, the *ectoderm*, *mesoderm* and *endoderm*, which together differentiate into all the cell types found in an adult (**Figure-6**).

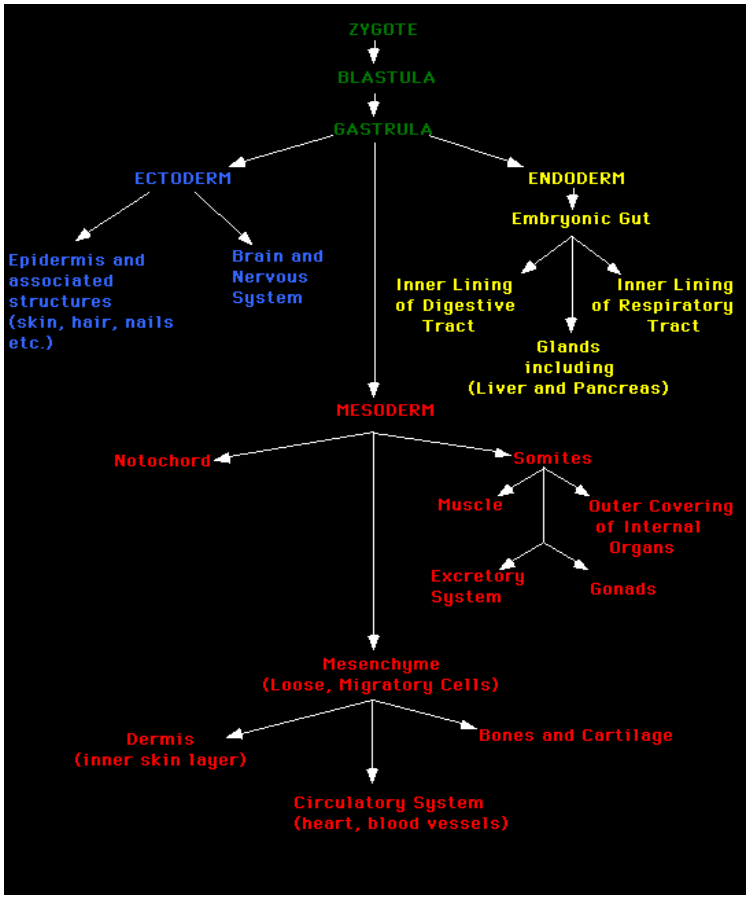

Figure-6: Differentiation of Ectoderm, Endoderm, Mesoderm Cells. Zygote division eventually leads to gastrulation and the formation of three germ cell layers: ectoderm (exterior layer), endoderm (inner layer) and mesoderm (middle layer). Together all three of these embryonic layers form all the tissues of the adult body. The ectoderm forms the nerves system and epidermis. Endoderm forms the epithelial lining. Mesoderm forms the mesenchyme, mesothelium and coelomocytes. (Loyola University, 2011)

Multipotent stem cells are less potent than ES cells. These cells form a few types of related cells. Examples include hematopoietic stem cells, which produce several kinds of blood cells, and neuronal stem cells which are responsible for the production of neuronal cells and neuroglial cells (Library of Congress, 2010). *Unipotent* stem cells are the least potent in terms of their ability to differentiate. These cells are able to make only one type of cell, usually the same as the tissue they are isolated from. For example, skin stem cells usually form only other skin cells.

Stem cell research is still ongoing and holds great potential. The study of stem cells will help scientists determine the complex signaling involved in the differentiation process, will allow the production of cell lines from patients with specific diseases, and will hopefully allow regenerative therapies to treat diseases (USA.gov, 2009).

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Chapter-2: Stem Cell Applications

Michael Gauvin

After discussing the various types of stem cells in the previous chapter, attention is now turned towards discussing how stem cells are used. This topic is important for understanding their benefits to society which are strongly weighed in discussions of stem cell ethics. This chapter describes four specific examples of the use of stem cells to treat diseases.

Leukemia and Stem Cells

The most practiced application of stem cells is the use of hematopoietic stem cells in treating leukemia. Each year in the United States, "more than 40,000 adults and 3,000 children develop this cancer of the blood cells" (Panno, 2010, pg. 99). This disease affects a type of white blood cell known as a lymphocyte that produces antibodies and plays a major role in the immune response. Mutations in the DNA of lymphocytes leads to a lack of maturation, so immature, non-functional lymphocytes accumulate in the bloodstream. Lymphocytes are derived from the process of hematopoiesis (**Figure-1**) from bone marrow stem cells. Treatment for leukemia patients usually includes radiation and chemotherapy to kill the cancerous lymphocyte cells, and in extreme cases involves the complete destruction of the patient's own bone marrow. The result of this process requires a bone marrow transplant from a compatible donor to replace the destroyed bone marrow (Panno, 2010, pg. 99-101).

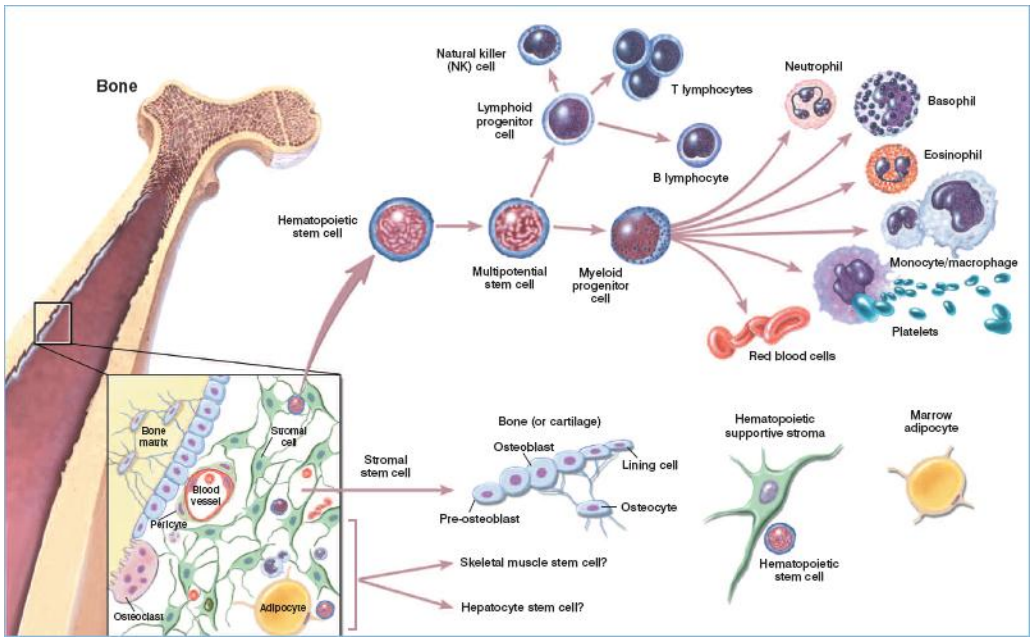

Figure-1: Diagram of Hematopoiesis. Shown are bone marrow derived stem cells and their potential to differentiate into the cellular components of blood, including lymphocytes. (NIH, 2006)

The process of using stem cells from bone marrow is by no means a new practice. In fact, "In 1956, three laboratories demonstrated that injected bone marrow cells directly regenerated the blood-forming system, rather than releasing factors that caused the recipients' own cells to repair irradiation damage" (NIH, 2006). Injection of HSCs is still the only known method to repair hematopoietic failure after radiation. Radiation treatments to kill rapidly dividing cancer cells began in the early 1960's (NIH, 2006), and is still in use today.

The success of bone marrow transplants is strongly related to the ability of the graft to survive, which is related to donor-recipient histo-compatibility. Acceptable donors for the bone marrow include close family relatives, such as parents and siblings, but graft-versus-host-disease (GVHD) can still remain a major threat. "Rates of GVHD vary from 30-40% among related donors and recipients, and from 60-80% for unrelated donors and recipients" (Hoffman et al., 2008.). Stem cell therapy can sometimes resolve GVHD problems by obtaining the cells from

the donor themselves. Bone marrow cells are taken from the patient, and attempts are made to isolate healthy from cancerous hematopoietic stem cells (HSCs). The HSCs are grown in culture, tested for known leukemia-causing DNA mutations, and inserted back into the patient to replace the marrow destroyed by chemotherapy (Panno, 2010, pg. 99-101).

In the past decade, new sources of hematopoietic stem cells have been investigated. Umbilical cord blood is highly enriched for HSCs, and because they are more primitive than bone marrow isolated HSCs they appear to induce less GVHD (Viacell, 2011). In addition, a recent discovery by researchers at the University of California Santa Cruz may make the harvesting of a patient's own stem cells even easier. A molecule named *Robo4* binds stem cells to bone marrow, so its elimination might allow for stem cells to be easily taken from the blood stream, instead of using injections of cytokine hormones to induce their release which produces side effects. According to study leader Camilla Forsberg, "If we can get specific and efficient inhibition of *Robo4*, we might be able to mobilize hematopoietic stem cells to the blood more efficiently" (Stephens, 2011). Further study of this molecule may also allow for easier expansion of the HSCs in culture.

Diabetes and Stem Cells

Diabetes is a disease that affects seven percent of the world's population, and is projected to rise to over 380 million people by 2025 (NIH, 2006). It is a metabolic disorder that inhibits the body's ability to make proper use of glucose, a large energy source for living cells. For Type-I diabetes, the problem arises in the pancreas (**Figure-2**), where insulin-producing β-cells lose their ability to function. Insulin is a hormone that stimulates the uptake of glucose from the blood into cells. A decrease in insulin production results in a buildup of glucose in the

bloodstream which can eventually lead to blindness, heart disease, stroke, kidney failure, and amputations (Panno, 2010, pg. 93-95). In type I diabetes, often called juvenile diabetes as it usually occurs at a younger age, the patient's white blood cells attack the pancreatic β-cells eventually destroying the body's ability to produce insulin and break down glucose.

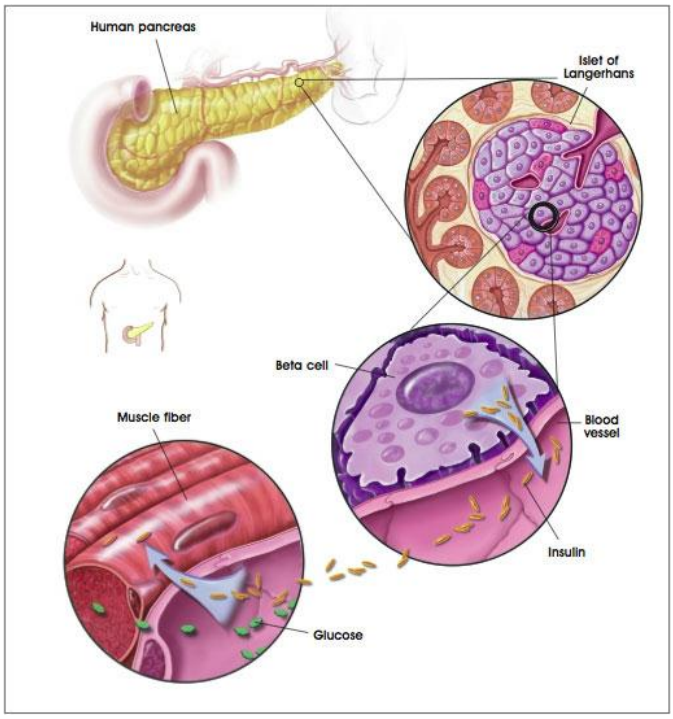

Figure-2: Diagram of a Healthy Human Pancreas. The pancreas (upper left) contains the Islets of Landerhans (upper right) that contain β-cells (lower right). The β-cells produce insulin that allows cells to take up glucose from the blood (lower left). (NIH, 2006)

One of the first major breakthroughs in treating diabetes with stem cells came in 2000, by the Institute of Bioengineering at the University Miguel Hernandez (Soria et al., 2000). The team was able to differentiate mouse embryonic stem (ES) cells *in vitro* to become insulin-producing cells. After the cells were implanted in the spleen of streptozocotin-treated diabetic mice, their hyperglycemia was corrected in one week, and their weight normalized after four weeks. The study showed that a mouse model of diabetes could be treated with mouse ES cells,

and suggested that there is major potential in this process for those afflicted with type-1 diabetes (Soria et al., 2000).

Research with human embryonic stem (hES) cells soon followed, and by 2001 researchers found, "Using hES cells in both adherent and suspension culture conditions, we observed spontaneous *in vitro* differentiation that included the generation of cells with characteristics of insulin-producing β-cells…. These findings validate the hES cell model system as a potential basis for enrichment of human β-cells or their precursors, as a possible future source for cell replacement therapy in diabetes" (Assady et al., 2001). Lumelsky et al. (2001) also showed the potential of human ES cells to differentiate *in vitro* into insulin producing cells. A similar study was performed in 2006 when Novocell Inc. induced hES cells to become pancreatic hormone-expressing endocrine cells. The cells are "capable of synthesizing the pancreatic hormones insulin, glucagon, somatostatin, pancreatic polypeptide and ghrelin" (D'Amour, 2006). Novocell tested these β-cell precursors in mice with interesting results. "The cells did not colonize the pancreas, but did produce insulin, and appeared to respond to normal physiological cues" (Panno, 2010, pg. 93-95). This experiment shows that the cells do not necessarily have to assimilate within the pancreas to produce insulin. Kroon et al. (2008) extended these experiments to show that human ES cells can be used to treat mouse models of diabetes. The use of human ES cells to treat diabetes has not made it to human clinical trials due to the fact that 7% of the treated mice appeared to develop cancerous tumors from the implanted cells. So this problem must first be solved before using ES cells to treat diabetes.

Efforts to direct the differentiation of adult stem cells (ASCs) and induced pluripotent stem (iPS) cells into β-cells are still being studied. In mice, adult pancreatic cells have been reprogrammed to secrete insulin (Zhao et al., 2008), and iPS cells have successfully been used to

treat mouse models of diabetes *in vivo* (Alipio et al., 2010). However, most scientists believe that ES stem cells offer the best cure for diabetes. "Harvard University researcher Douglas Melton… pointed out that in mice, new β-cells in the pancreas are normally formed through the replication of existing β-cells rather than through the differentiation of adult stem cells.

Cardiovascular Disease and Stem Cells

According to the World Health Organization (WHO) cardiovascular disease is the number one cause of death worldwide, killing over 17 million people. This number is projected to rise to over 23 million by the year of 2030, with the majority of deaths occurring from heart attacks (WHO, 2011). Heart attacks result from an obstruction of blood supply to the heart which can lead to the death of cardiac muscle. Varying degrees of damage to the heart muscle cells (cardiomyocytes) range from minor inability to pump blood effectively, to complete failure of the organ (Panno, 2010, pg. 93-95). Stents and by-pass surgeries are sometimes successful with some patients, but organ transplant remains the only treatment for complete cardiac failure, a procedure that is both dangerous and extremely expensive. According to Transplant Living, as of 2007 the average total cost of a heart transplant was $787,700, with the possibility of organ rejection and a life of anti-rejection medications still ahead of them (Transplant Living, 2011).

Stem cell therapies to treat this disease would be one of the greatest advancements in medicine to date. Among the first attempts to use stem cell therapy to treat cardiac failure was done by researchers at the National Institutes of Health (NIH) in 2001. The team induced heart attacks in mice and injected them with adult stem cells extracted from mouse bone marrow. "The researchers found that newly formed myocardium occupied 68% of the damaged portion of the ventricle nine days after transplanting the bone marrow cells. The developing tissues appeared to consist of proliferating cardiomyocytes and vascular structures" (Panno, 2010, pg.

89-92). This experiment was soon extended by Kocher et al. (2001) who used human bone marrow-derived stem cells to treat mouse models of ischemia.

These impressive animal results with bone marrow stem cells led to over 30 Phase I human clinical trials for cardiovascular disease by 2008. One of the most promising studies came with the implantation of skeletal myoblasts into akinetic/dyskinetic area of the damaged heart (Siminiak et al., 2004). The results of the procedure were interesting. "The left ventricular ejection fraction increased from 25% to 40% (mean, 35.2%) before the procedure to 29% to 47% (mean, 42.0%) during the 4-month visit ($P < .05$), and the improvement was maintained throughout 12 months of follow-up" (Siminiak et al., 2004).

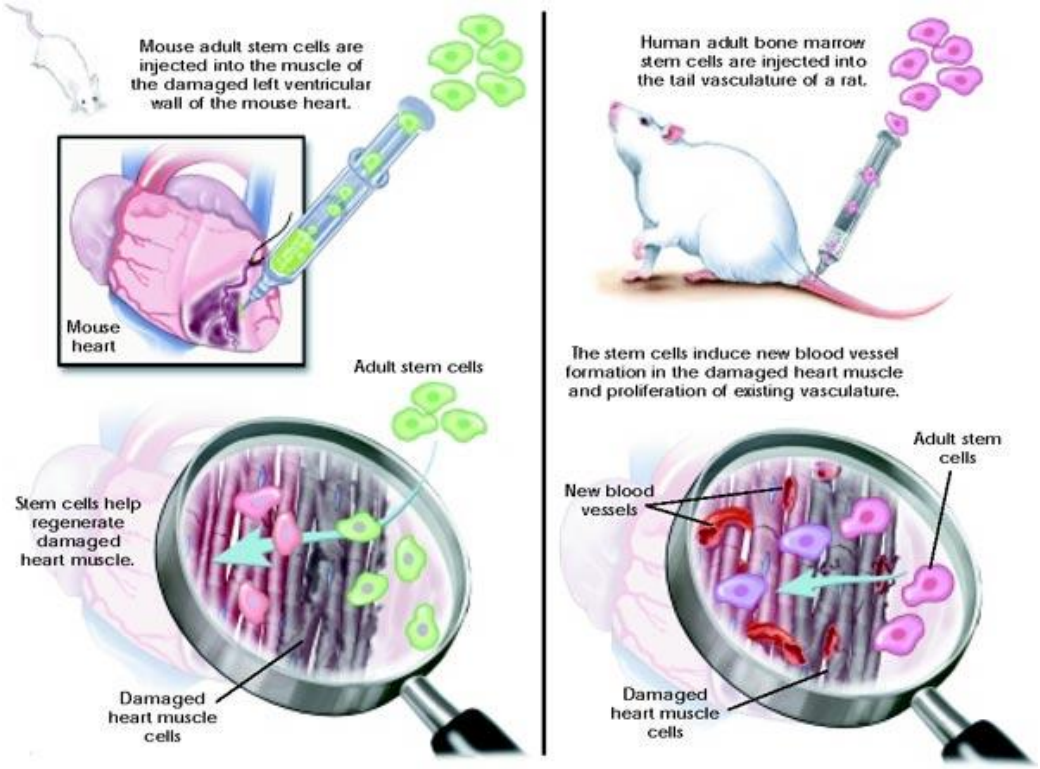

Figure-3: Diagram of Treating Heart Attacks with Stem Cells. Scientists have tested the injection of mouse bone marrow stem cells delivered directly into the heart (upper left) and human bone marrow stem cells injected into the tail vein (upper right). The former procedure led to a 68% regeneration of the damaged tissue. (NIH, 2011)

The initial success using skeletal myoblast cells in human patients by Siminiak et al. (2004) was followed in 2006 by treatment of patients with bone marrow-derived stem cells (Lunde et al., 2006; Schächinger et al., 2006).

Others believe that these adult stem cell treatments hold much less potential than ES cell treatments. According to Professor Joseph Panno, the procedures with injections of the patient's own bone marrow-derived stem cells seemed to provide little improvement in cardiac function. Although the cells expressed some key marker transcription factors of cardiac cells, they did not appear to restore function strongly (Panno, 2010, pg. 90). He believes the small improvements were "likely due to factors released by the transplants. Thus, some scientists believe ES cells have the most long term potential for treating cardiovascular disease. Researchers such as Izhak Kehat have had success in differentiating human ES cells into cardiomyocytes. According to a 2001 article, "the human ES cell–derived cardiomyocytes displayed structural and functional properties of early-stage cardiomyocytes. Establishment of this unique differentiation system may have a significant impact on the study of early human cardiac differentiation, functional genomics, pharmacological testing, cell therapy, and tissue engineering"(Kehat et al., 2001). However, ES cells have their drawbacks. In addition to their ethical issues, graft-versus-host disease (GVHD) is always a threat as the cells would be allogeneic, derived from someone other than the patient themselves. And the development of teratomas is also a possibility. This occurs when not all of the injected cells integrate with the cardiomyocytes, so they migrate elsewhere, triggering tumor formation.

Parkinson's Disease and Stem Cells

Parkinson's disease (PD) is a neurodegenerative disease that affects an estimated four to six million people world-wide (National Parkinson's Foundation, 2011). The disease attacks the neurons in the substantia nigra which produces dopamine (**Figure-4**). The loss of dopamine affects neuromuscular transmission, causing tremors, muscular stiffness, and balance (Panno, 2010, pg. 107, 108).

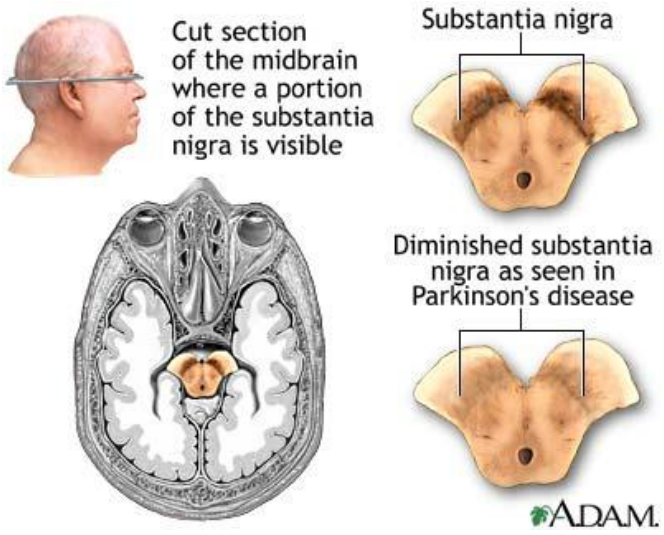

Figure-4: Brain Areas Affected by Parkinson's Disease. This figure shows the effect of Parkinson's disease on the substantia nigra which secretes dopamine neurotransmitter. (Medline Plus, 2011)

Stem cell therapy might be a treatment for this disease because the damage is isolated to one area of the brain. Some of the first attempts to treat human Parkinson's patients with cell therapy were performed in 1988, treating PD patients with fetal tissue implants obtained from aborted fetuses (Madrazo et al., 1988). In 1998, implantation of neurological precursors was studied in an effort to produce dopaminergic neurons (the neurons which populate the substantia nigra). According to an article published by *Nature Neuroscience*, "CNS precursor cell

populations expanded *in vitro* can efficiently differentiate into dopaminergic neurons, survive intrastriatal transplantation, and induce functional recovery in hemiparkinsonian rats" (Struder, 1998). This groundbreaking procedure gave great promise to the use of neural stem cells (NSCs) to eventually cure Parkinson's in humans.

In 2004, scientists showed that human ES cells could be differentiated into midbrain neurons capable of producing dopamine (Perrier et al., 2004). A paper was published in 2009 on the use of these NSCs to treat a Parkinson's patient by neuroscientist Steven Ertelt. According to Ertelt, "We have documented the first successful adult neural stem cell transplantation to reverse the effects of Parkinson's disease, and have demonstrated the long term safety and therapeutic effects of this approach." The group extracted the NSCs from a PD patient, expanded them *in vitro*, induced them to become mature dopaminergic neurons, and finally injected them back into the affected part of the patient's brain (Ertelt, 2009). The results of the procedure produced impressive results. The patient sustained an 80% increase in his motor skills, sustained for at least 5 years after the surgery (Ertelt, 2009). The procedure produced no tumors, a problem that often arises after ES cell implantations. It is also important to note that the stem cells used were derived from the patient himself, lowering the possibility of rejection. Thus, for this application of treating Parkinson's disease, the use of adult stem cells appears to have more promise than using ES cells, as it eliminates most of the ethical issues while producing no tumors.

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Chapter-3: Stem Cell Ethics

Michael Gauvin

After discussing the various types of stem cells and their uses in previous chapters, attention is now turned to whether such cells should be researched. The discussion of stem cell ethics weighs the balance between the benefit to society (discussed in chapter-2) versus the destruction of the embryo (for embryonic stem cells). The views of some of the major world religions will be used as an outline for investigating when life begins and the status of the human embryo.

Adult Stem Cell Ethics

Contrary to popular belief that religions do not support the use of "stem cells", most of the world's major religions support the use of adult stem cells to save human lives (Pope Benedict XVI, 2008). Adult stem cells (ASCs) do not destroy embryos during their isolation. Promising advances in ASC and induced pluripotent stem (iPS) cell research may someday put an end to the ethical issues of using ES cells. However, medically there are some drawbacks to using ASCs. As pointed out in Chapter-2, ASCs do not appear to work well for some types of diseases, including heart attacks. ASCs do not appear to be able to differentiate into as many tissues as ES cells, they are harder to isolate and harder to grow (NIH, 2006). Thus, whenever possible, scientists continue to work with ES cells.

Embryo Ethics

With respect to embryonic stem (ES) cells, the ethical debate focuses on the status of human embryos. As discussed in Chapter-1, ES cells are isolated from the inner cell mass of 5-day old IVF blastocysts which are usually destroyed in the process. So the debate focuses on when life begins relative to the 5-day old blastocyst. Is it murder to harm this embryo?

A document called the Belmont Report is an extension of the Hippocratic Oath, and provides ethical guidelines to physicians. The Hippocratic Oath states, "I will give no deadly medicine to anyone if asked, nor suggest any such counsel" (Panno, 2010). Thus, physicians cannot harm their patients in their research even if it may benefit another. The Belmont Report also adds two extra components: 1) the idea of informed consent requires written consent from a research subject before any trials can be done, and 2) the idea of a patient's advocate who makes sure any research is explained clearly to the test subject. With respect to ES research, many ethicists believe that the Belmont report suggests that "a human embryo or fetus, incapable of giving informed consent, should be afforded the benefit of an advocate" (Panno, 2010). If this is true we can clearly see how important the question of the beginning of life becomes.

Religions and ES Cell Ethics

Religions can provide a framework for the question of when life begins. We will see how this question of the beginning of life greatly affects the viewpoints of these groups on the subject of embryos and ES cells. For example, some religions believe that ensoulment occurs at the moment of conception, and from that point on the embryo has the rights of any other living person. Other religions disagree with this idea, and believe the embryo is a soulless, unconscious entity until at least the fortieth day of development. And some religions give weight to whether

the stem cell experiments are performed to increase longevity and improve the quality of life of the human race. Some religions believe that it is their duty to solve problems in the world. We will see how religions must balance their embryo beliefs with their desire to improve human life.

Catholics and Stem Cells

Many are aware that the Catholic faith believes that the destruction of the embryo for any means is seen as deliberate murder of a human being. The Congregation for the Doctrine of the Faith issued a statement in February 22, 1987, known as the *Donum Vitae*, which states that the "human being is to be respected and treated as a person from the moment of conception and therefore from that same moment his rights as a person must be recognized" (Shannon 2002). The Catholic belief that life begins at conception is a major contributor to opposition to ES cell research. Pope John Paul II gave his opinion on the matter in 2001 in response to President Bush's decision to allow federal government funding for 64 stem cell lines:

> "Experience is already showing how tragic coarsening of consciences accompanies the assault on a human life in the womb, leading to accommodation and acquiescence in the face of the related evils such as euthanasia infanticide and, most recently, proposals for the creation for research purposes of human embryos, destined to be destroyed in the process." (Wagner, 2008)

Judaism and Stem Cells

The Jewish interpretation of religious texts leads to a very different stance on the issue of stem cells. Many Jews believe they have a responsibility to repair the broken world, a concept known as *Tikkun Olam*. According to Jewish ethicist Eliot Dorf, "The potential of stem cell research for creating organs for transplantation and cures for diseases is, at least in theory, both awesome and hopeful. Indeed, in light of our divine mandate to seek to maintain life and health,

one might even contend that from a Jewish perspective we have a duty to proceed with that research."

The Jewish religion also does not see conception as the starting point of human life. The *Talmud*, a central text in Judaism, states that an embryo is "mere fluid" until forty days after conception (Bennet, 2011). There is also a popular Jewish belief that embryos outside the womb, such as leftover embryos from IVF, do not have the potential to become human beings. Therefore the destruction of an early embryo is not looked at as infanticide as it is in the Catholic religion, and Jewish ethicists see these entities as great opportunities for human healing (Yearwood, 2006).

There is however, some disagreement in Judaism in the case of creating embryos solely for research purposes versus using excess IVF embryos. Dorff himself, a proponent of stem cell research, said, "creating an embryo specifically to be the source of stem cells is permissible, but less morally justifiable." Others such as Rabbi Aaron Mackler, a conservative expert in bioethics and Jewish law, believes that, "There is potential life… and we need to respect that and be cautious" (Yearwood, 2006).

Islam and Stem Cells

Islam theology has a similar stance to that of Judaism on the issue of stem cell research. Ethicists of this religion use the Qur'an, the main authority of Islam to determine the standing of the embryo, "We created man of an extraction of clay, then we sent him, a drop in a sage lodging, then we created a drop of clot, then we created a clot of tissue, then we created the tissue of bones, then we covered the bones in flesh; thereafter we produced it as another creature. So blessed be God, the best of creators (Chapter 23, verse 12-14)." Some believe this passage

implies an embryo is not alive until at least 40 days of development. Others believe that ensoulment does not occur until one hundred and twenty days after conception. based on this passage: The embryo exists forty days as a drop of matter, forty days as a blood clot, and forty days as a blob until an angel breathes life into it (Weckerly, 2006). The blastocyst is not considered a human being at conception as in Catholic belief, and its destruction is not seen as "murder". This belief makes Muslims much more likely to be supporters of ES cell research.

Another factor that leads Islamic ethicists to be proponents of this research is the importance of inheritance rights and the prohibition of surrogate parenting. For example, if a Muslim were to choose IVF they would want the excess embryos destroyed. This would eliminate the possibility of future children with their genetic information from a surrogate mother to claim inheritance. However, rather than wasting excess IVF embryos, some Muslims choose to donate their zygotes to laboratories (Bennet, 2011).

Hinduism and Stem Cells

The religion of Hinduism contains a firm belief that all life is sacred whether it is plant, animal, or human. There is however, a hierarchy in this system, and followers of the religion know they have to consume to survive. This hierarchy is based on the level of consciousness of the organism: where humans are on the top, below which are animals, and the lowest level contains plant life. In Hinduism, the soul is reincarnated throughout a number of different species until it reaches its highest level of consciousness, human life. The final step after being born human is ending the cycle of reincarnation and uniting with God. Hindus put great importance on extending the longevity of life as it would allow them more time to become closer to God and break this reincarnation cycle. They believe that using unconscious embryos to

improve the overall quality of life of a conscious human life is absolutely morally acceptable (Bahnot, 2008).

Buddhism and Stem Cells

Traditional Buddhist teachings seem to contradict one another on the matter of stem cell research, which clouds the waters on the subject. Buddhists place a very high prominence on the virtue of knowledge, which they call *"prajna".* This, along with the importance of compassion, "karua", would lead one to believe that they would welcome ES research as it would provide them with great knowledge and help alleviate a large amount of human suffering. The problem arises when one considers the belief of continual rebirth, and the fact that Buddhists believe that life starts at conception. The newly formed embryo is given the same moral status as a recently deceased individual, which is seen as equal to that of a living being. The idea of "ahimsa", the protection of living things, makes the concept of embryonic stem cell research morally impermissible (Keown, 2004).

iPS Cell Ethics

Induced pluripotent stem (iPS) cells are adult somatic cells reprogrammed to have some of the same potential as embryonic stem cells. From an ethical standpoint, iPS cells avoid many of the problems that ES cells face, as no embryos are destroyed. iPS cells steer clear of this problem because the cells are derived from an ordinary human skin fibroblast cell. The skin cells are treated with a virus vector or proteins that reprogram the cells to a state of pluripotency. This also solves the problem of possibly harming female donors as eggs are not needed for the process (NIH, 2006).

However, some scientists argue that iPS cells are harder to grow than ES cells, and may contain cancer-causing DNA mutations (Doglin, 2010). And some scientists argue iPS cells may not be truly pluripotent. Thus, more research is required to determine their true potency and whether their use causes cancer. Another problem that may arise in the future is the prospect of creating human life from iPS cells if they are ever shown to be totipotent. If it is possible to create a totipotent cell from these chemically reprogrammed skin cells, it may be possible to create a living being from them, which constitutes reproductive cloning. If this is accomplished, a number of legal and ethical problems would emerge, as stated by Timothy Caulfield of the University of Alberta's Health Law Institute:

> "From a legal perspective, iPS technology is fascinating and complex. For example, if an iPS cell can be made into a functional human gamete, the potential exists for reproductive purposes. What would this mean for donor consent, concerns about cloning and rights of a potential child to know its parents….What could this mean to assisted reproduction practices and would-be parents with no other option? If anything, we know considerable thought and policy development needs to be placed around these and other issues." (University of Alberta, 2009)

Author Conclusion on Embryo Use

The author of this chapter is not against the use of embryos in stem cell research under any circumstances. I offer you an analogy from Michael J. Sandel:

> "Although every oak tree was once and acorn, it does not follow that acorns are oak trees, or that I should treat the loss of an acorn eaten by a squirrel in my front yard as the same kind of loss as the death of an oak tree felled by a storm. Despite their developmental continuity, acorns and oak trees differ. So do humans embryos and human beings, and in the same way. Just as acorns are potential oaks, human embryos are potential human beings.
> The distinction between a potential person and an actual one makes a moral difference. Sentient creatures make claims on us that consentient ones do not; beings capable of experience and consciousness make higher clams still. Human life develops by degrees." (George, 2005)

The stage of the embryo is very important to note. In 1994, the *Report of the Human Embryo Research Panel* (HERP) stated that, "protectability is not an all-or-nothing matter but results from a being's increasing possession of qualities that make respecting it more compelling" (NIH, 2006). This view has been around for thousands of years and was even shared by the Greek philosopher Aristotle who believed that life develops through three stages: vegetative, animate, and intellectual. The first two stages were completed in the womb, but the final stage comes only after developing an intellect and collected experience. An interesting thing to consider when looking at this subject is the fact that parents would be much more likely to grieve the loss of their newborn child rather than the death of an embryo through miscarriage. Thus, in the author's view, a 5 day old blastocyst with the potential for life does not have the same status as a living being.

When accessing the ethics of stem cell research, one of the most crucial areas to consider is the individual *identity* of the embryo. This individual identity is necessary for the embryo to have moral rights. At the point of about 5 days after conception, this embryo is merely a group of undifferentiated cells with no consciousness or experience (Lindsay, 2006). If we were to treat this entity with the same rights as a fully developed human we would be forced to treat each cell in the human body with the same rights.

The phenomenon of twinning also provides some other problems with the theory of personhood at conception. It is possible for the embryo to divide and develop into a separate human being until the third week of development. From this evidence we can conclude that there is no determinate individual at the moment of conception. We can also argue that because twins are not completely identical to each other, the embryo is not necessarily identical to the humans they develop into (Lindsay, 2006). One could pose an interesting argument with the fact

that twins have different points of origin: if it is true that all persons exist at the moment of conceptions, does that then mean that one of every set of twins is not human?

Some argue that leftover embryos should not be used for stem cell research as they were originally developed for the purpose of creating life. I think this view may come from a lack of understanding of the process of *in vitro* fertilization. Embryos have no potential to become a human until they are implanted into a woman's uterus. As stated by Ronald A. Lindsay, "Their potential is no more than a theoretical construct." These embryos will simply be kept in frozen storage and eventually be discarded if not used. According to James Thomson developmental biologist at Wisconsin University, "There are over 400,000 frozen embryos in the United States, and a large percentage of those are going to be thrown out.… It's a better moral decision to use them to help people" (Lindsay, 2006) It seems to me that it is unethical if we do not take advantage of these frozen embryos, as they have great potential to save lives and would otherwise be wasted.

I am also in favor of using embryos created solely for the purpose of research because these do not have the potential to become human, and to me this resolves a major ethical question the subject is faced with. For example, in somatic cell nuclear transfer (SCNT) there is no sperm-egg fertilization. Instead, a somatic cell nucleus is inserted into an egg cell and an electrical trigger causes it to begin dividing. We see here that there is absolutely zero potential for this blastocyst to become a living being unless it is intentionally implanted into a human uterus (Lindsay, 2006). SCNT also serves as a method to disprove the "argument from potential". "Through SCNT, a somatic cell is allowed to express its potential to be transformed into an embryo that is latent in its genes but has been suppressed. If gene-based potential to develop into a person is sufficient to provide an entity with full moral status, then each somatic

cell in a human person's body has the same rights as the person herself" (Lindsay, 2006). I personally find this conclusion to be completely unacceptable. Treating each cell in the human body with the same rights as the person from whom it was derived would deem much of modern medicine immoral.

I am in favor of using adult stem cells instead of embryonic stem cells if they can produce the same medical results. So far, ES cell research is proving to have much more potential than ASCs. ASCs are much less versatile, and cannot differentiate into as many different types of cells. ASCs are also not as easy to grow in culture compared to ES cells. One positive to the use of ASCs is that they are much less likely to be rejected by the patient due as they are derived from the patients themselves (NIH, 2006). This type of graft, known as an autologous graft, would relieve the patient of a life taking anti-rejection medication and the possibility of graft-versus-host disease (GVHD) (NIH, 2006). Because ASCs resolve the major ethical issue of ES cell research, I encourage their use whenever possible. I would however, rather see more federal funding for ES cell research, as I believe it holds much more promise.

I am also in favor of using iPS cells for many of the same reasons. Although iPS cells still require much further research to determine their true level of potency and to determine whether they carry DNA mutations, I believe they have great potential. Like ASCs, iPS cells avoid many of the ethical problems of ES cells because they are derived from adult somatic cells, leaving the question of the beginning of life and the concept of murder out of the debate. One of the only remaining ethical issues would be the possibility of creating life from iPS cells if they are even shown to be totipotent, however this has not occurred. iPS cells are also thought to have an extremely low rejection rate, as they can be derived from adult skin cells taken from the patients themselves and reprogrammed for transplantation (NIH, 2006). I believe iPS cells

should be used whenever possible, as they resolve the ethical issues of ES cells. However, I do not share the view that ES cell research is wrong, and likewise believe that the majority of research should be focused in that area.

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Chapter-4: Stem Cell Legalities

Hashim Ismail

Stem cells, and in particular those derived from human embryos, bring both controversy and promise. Since the first successful isolation of human embryonic stem cells (hESCs) by James Thomson of the University of Wisconsin in 1998 (Thomson et al., 1998), these cells have risen to become one of the hottest and most controversial subjects of the 21st century. hESCs are unspecialized, nature's master cells that can divide into any of the more than 200 specialized cells of the body. From various religious beliefs, to political and humanitarian arguments, this subject has caught the attention of renowned leaders of our era. These cells are believed to hold cures for a myriad of deadly diseases ranging from cancer to neurodegenerative and heart diseases.

But does this medical benefit to society grant us the permission to destroy human embryos? hESCs are isolated from the inner cell mass of a 5-day old embryo prepared by *in vitro* fertilization (IVF). Addressing an international congress in 2008, Pope Benedict XVI noted "*the destruction of human embryos to harvest stem cells is "not only devoid of the light of God but is also devoid of humanity" and "does not truly serve humanity" (Catholic Online, 2008). The stem cell ethics debate (discussed in Chapter-3) is reflected in the complex assortment of laws regulating stem cell and embryo use in various countries.* This chapter will discuss current federal and state regulations of the US, as well as international laws governing stem cell research.

Early US Embryo and Stem Cell Legalities

The US laws governing embryos and stem cells has varied considerably, depending on which elected president is in office, congress, and the people's views and education about the subject matter. In the US, the past few decades witnessed a suppression of hESC research. *Since the development of human IVF techniques in the late 1960's until now, the fate of the extra unwanted human embryos not used for reproduction has been debated.* According to Meredith Ebbin in her article "How other countries regulate stem cell clinics," top US scientists acknowledge the ethical issues involved in ES cell research, but they confirm that the public discussion on ES cells in the US is sometimes based on misinformation and emotionally charged discussions (Ebbin, 2006).

In 1973 *Roe v Wade*, the United States Supreme Court legalized certain types of abortions, allowing fetal tissue to be used for research purposes (Roe v Wade, 1973). This Supreme Court decision fueled the onset of endless ethical debates surrounding abortion (Morales, 2009). In 1979, President Carter, because of continued pressure from anti-abortion groups, disbanded the Health and Human Services Department advisory board that examined federally funded research on human sperm, eggs, and embryos (Smith, 1989). As the anti-abortion movement continued, political pressure continued to build, forcing President Ronald Reagan, and later George Bush, to block federal funding for research on human embryos.

The Clinton Administration

Stem cell research in the US is strongly linked with the politics of abortion. Bill Clinton's stance on abortion was clear, as he writes "Everyone knows life begins biologically at conception. No one knows when biology turns into humanity…I thought then [in the 1973 Roe

v. Wade decision] and still believe that the Court reached the right conclusion" (Clinton, 2004). To a large extent, Clinton also supported stem cell research. In 1993, under President Clinton, the US Congress enacted the NIH Revitalization Act, giving NIH authority to fund human embryo research for the first time (Dunn, 2005). The NIH then established a panel to consider the moral and ethical issues involved, and to determine which embryos should receive federal funding. In 1994, this NIH Human Embryo Research Panel (HERP) made its recommendations to President Clinton, permitting the funding of stem cells derived from excess IVF embryos from fertility clinics (Dunn, 2005).

Due to public outrage, Clinton rejected some of the recommendations made by HERP, and informed NIH not to fund any research involving the creation of new embryos solely for research. In response to further criticism, in 1995, Congress enacted the *Dickey-Wicker Amendment* which banned all embryo research (Robertson, 2010). Ever since, Congress has continually renewed the ban each year.

The Bush Administration

Under the presidency of George W. Bush, stem cell research witnessed severe oppression. Coming from a conservative Christian background, Bush opposed hESC research, stating "While we must devote enormous energy to conquering disease, it is equally important that we pay attention to the moral concerns raised by the new frontier of human embryo stem cell research. Even the most noble ends do not justify any means." (President George W. Bush's address on stem cell research, 2001). The election of republican George W. Bush as President, with a republican majority in the House of Representatives, gave conservatives the upper hand. On August of 2001, President Bush extended congresses' *Dickey-Wicker* ban to cover all hESCs,

with the exception of those cell lines created prior to his announcement (House, 2001). This meant that federal funding would now be restricted to only those cell lines created before his announcement. But the viability and pluripotency of these cell lines have raised a lot of questions. This decision stopped support to many promising avenues of biomedical research in an effort not to "sanction or encourage further destruction of human embryos" (Dunn, 2005). Within months, Bush further ordered an official removal of funding guidelines that Clinton had initially authorized. Thus, Bush became the first president to reduce the amount of hESC research eligible for federal funding.

President Bush let his ethical belief get in the way of his decisions, and he continued to veto all legislations aimed at loosening the ban on hESC research. He used his first veto power as a president after about 5.5 years in office against a stem cell bill, saying that the Senate's Stem Cell Research Enhancement Act of 2005 "crossed a moral boundary" (Bash and Walsh, 2006). The bill, which the Senate had passed 63-37, would have loosened the restrictions on federal funding for stem-cell research. In 2007, President Bush vetoed a second bill, similar in content to the previous Senate bill, claiming that scientific advances now allow researchers to pursue the potentially lifesaving work without destroying human embryos. In his message to Congress after the veto, Bush stated "The Congress has sent me legislation that would compel American taxpayers, for the first time in our history, to support the deliberate destruction of human embryos" (Fletcher, 2007).

Bush's stance against hESC research was not largely reflected by the US public. According to a 2007 Gallup Poll (**Figure-1**), even though about 64% of Americans said that Bush should not veto the stem cell bill earlier that year (Carroll, 2007), he still did, saying that the legislation crossed an ethical line.

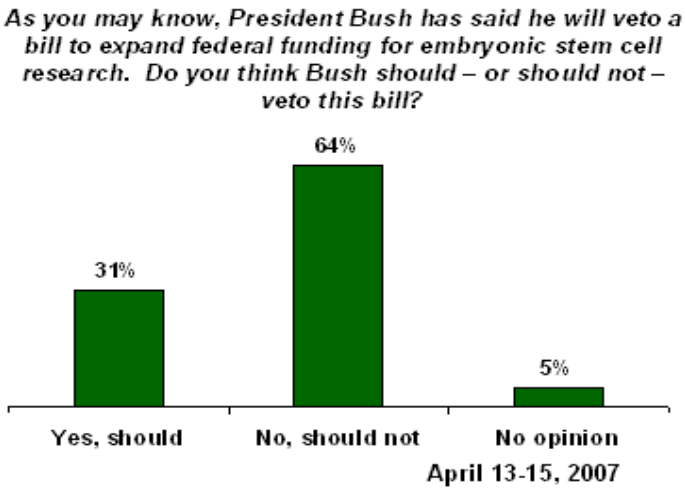

Figure-1: Public Support of Stem Cells 2007. A Gallup Poll in 2007 shows that 64% of Americans were against Bush vetoing the stem cell bill in 2007. (Carroll, 2007)

US States Response to Bush Policies

As the federal funding of hESC research under Bush decreased, individual states passed laws funding private institutions for continuing the research. In an effort to keep and attract top scientists and biomedical researchers, individual states in the US under Bush were forced to find ways of keeping stem cell research alive. Several US states launched campaigns against the national policy that limited federal funding to the previously derived hES cell lines (**Figure-2**). To date, states like California, New Jersey, New York, Massachusetts, Illinois, Maryland, Connecticut and Wisconsin are leading the way with both political and financial support (Wadman, 2008).

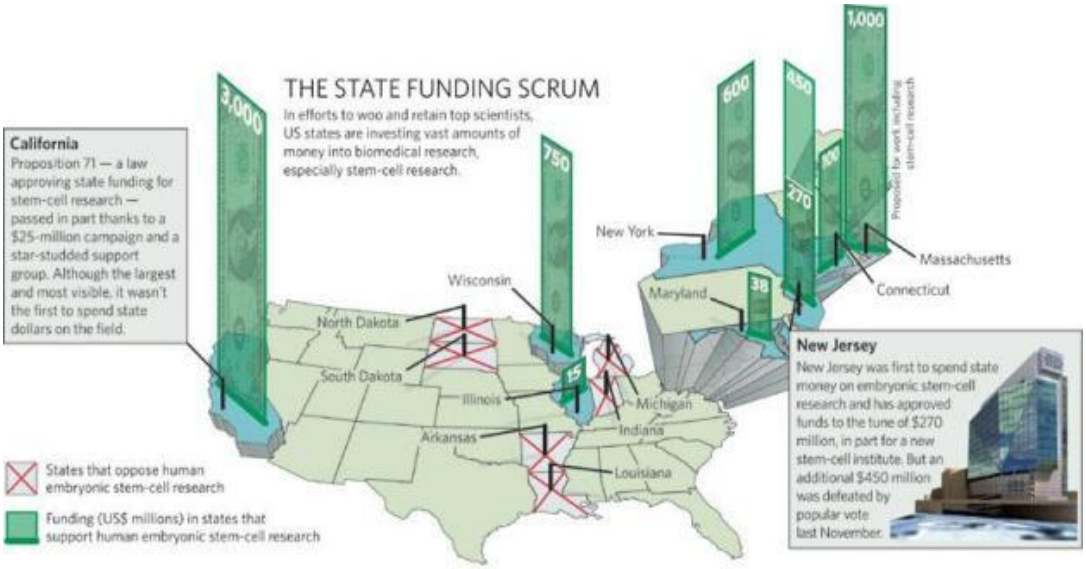

Figure-2: Individual US State Embryonic Stem Cell Research Policies. The map shows the distribution of state stances on stem cell research. This figure points to the states that are leading the research with the most amount of finanacial support, as well as states that prohibit the practice. (Wadman, 2008)

As seen in figure-2 above, California tops the list financially. In 2004, California passed proposition 71, with the support of 59% of California voters. This bill provided 3 billion dollars, over the course of 10 years, to advance stem cell research in the state (Hayden, 2008). However, they were not the first state to spend state money for funding the research. Earlier in the same year, New Jersey was the first state to spend public money to fund ES cell research by appropriating $10 million for the research, including the building of the Stem Cell Institute of New Jersey. But California's large scale funding encouraged many other states to follow on a similar path. According to Christine Vestal in "States take sides on stem-cell research," States such as New York, Connecticut, Illinois, Maryland, Wisconsin and Massachusetts took a similar path, funding the research as well.

In June 2005, Connecticut Governor M. Jodi Rell signed a measure providing $100 million in state funding over 10 years for embryonic stem cell research (Vestal, 2008). Following that in the same year, Illinois Gov. Rod Blagojevich directed the public health department to grant $10 million to stem-cell projects over 10 years, before adding $5 million more to the fund in July 2006. Also, Gov. Robert Ehrlich of Maryland signed a measure in 2006 appropriating $15 million in to be distributed in 2007. Following the loss of his election, first-term Gov. Martin O'Malley then appropriated an extra $23 million for distribution in 2008. Furthermore, Wisconsin Gov. Jim Doyle created $750 million investment fund to build the Wisconsin Institutes for Discovery, which will house the research facility for embryonic stem cell studies. The state of New York also signed a budget measure in 2007 that sets aside $600 million for stem-cell research over the span of 11 years under Gov. Eliot Spitzer, and Massachusetts Governor Deval Patrick proposed a $ 1 billion package to promote life sciences and stem cell research in the state (Vestal, 2008).

It was not surprising that Massachusetts, the home of leading research institutions like Harvard, MIT, and the University of Massachusetts Medical School, and a hub for biomedical research from Worcester to Boston, followed on a similar path. Headed by Senate President Robert Travaglini in 2005, the senate passed a bill to promote stem cell research in the state, while at the same time explicitly banning human *reproductive* cloning, and established penalties for those who abuse it (Finer, 2005). But the republican governor at the time, Mitt Romney, vetoed the bill claiming it would allow the cloning of human embryos—a practice that he termed as "morally wrong" (Romney, 2011). But this action did not sit well with the state senate, and the bill was vetoed, overriding the Governor's veto 35 to 2. In 2007, under the new leadership of Massachusetts Governor Deval Patrick, in an effort to promote the state's already existing global

leadership in the life sciences, he proposed a $1 billion state investment package. This package will provide grants for university and hospital scientists, train and cultivate talent for the biotechnology business, and establish research centers in the area ensuring the state's ability to support the progress of life sciences and cutting edge biomedical research. Governor Patrick's plan was very important for the scientific community, especially after Governor Romney's previous opposition towards ES cell research. State legislators were supportive of Patrick's plan, and it was approved in June of 2008. The highlight of this effort was the establishment of the nation's largest embryonic stem cell bank at the University of Massachusetts Medical School in Worcester. The Massachusetts Human Stem Cell Bank will be a 15,000 square foot facility that cultures, characterizes and provides hESCs to the research community globally. This investment turned out to be even bigger, when the University of Massachusetts Human Stem Cell Bank and Registry and the United Kingdom Stem Cell Bank signed an agreement in March of 2011. The agreement, which was part of Governor Patrick's Innovation Economy Partnership Mission will allow both facilities to share best practices for stem cell banking and to collaborate on standards for stem cell line characterization, production, and distribution in the US and UK (Fessenden, 2011). This is an important step to promote stem cell research in Massachusetts, and as Governor Patrick said, "the future of life sciences is here in Massachusetts… We have the talent. We have the entrepreneurial spirit. Now let's seize the future" (Patrick, 2007).

Although the list of US states supporting ES cell research is growing, the number remains low overall. Some states like Iowa and Missouri have legalized the research, but have not provided any funding. Other states such as Arkansas, Indiana, Louisiana, Michigan, North Dakota and South Dakota have restricted the practice. But the issue remains unsettled in much of the country, and the majority of the states have no legislations addressing ES cell research.

Even though state funding is not a replacement for larger amounts of federal money, such money will make a difference in the progress of stem cell research, and ultimately in the lives of those who carry hope.

Current Obama Administration Policies

While the future of hESC research is uncertain, the present looks promising. In 2009, the inauguration of President Barak Obama, a democrat, opened new doors to hESC research in the United States. Within months of his presidency, Obama used his executive order to lift the restrictions on federal funding for responsible research involving hESCs. This ended an 8½-year ban on federal funding for embryonic stem cell research under the Bush Administration. President Obama shows support for ES cell research and science in general, promising that his administration will make "scientific decisions based on facts, not ideology" (Childs and Stark, 2009). As part of his speech before signing the order, he said "We will lift the ban on federal funding for promising embryonic stem cell research…We will vigorously support scientists who pursue this research. And we will aim for America to lead the world in the discoveries it one day may yield" (Childs and Stark, 2009). The most immediate outcome of this promise will allow federally funded researchers to use hundreds of new embryonic stem cell lines for research in hopes of creating better treatments, possibly even cures, for many of man's worst health conditions (Borenstein and Feller, 2009).

This presidential decision appears to be supported by the majority of the American people according to a 2009 Gallup poll (**Figure-3**) (Morales, 2009). The poll shows that 38% of Americans said they support easing Bush's restrictions, and another 14% said they favor no restrictions at all.

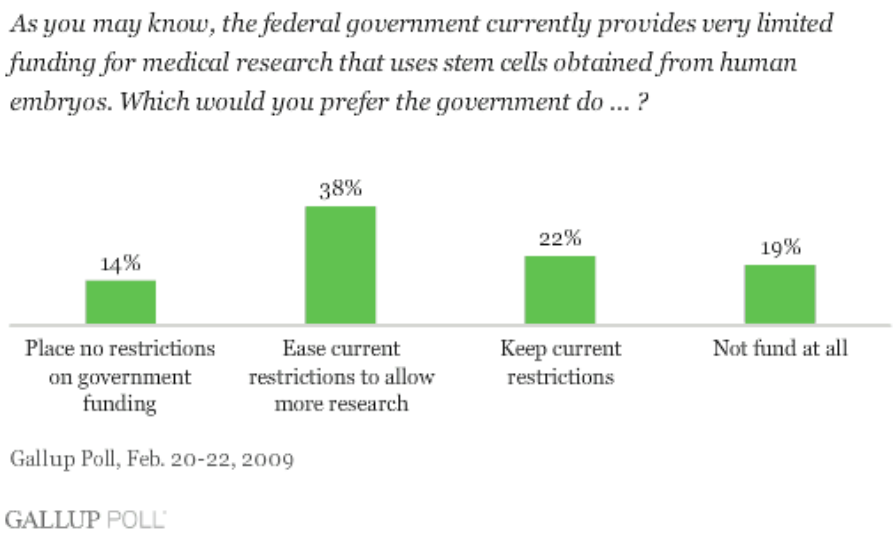

Figure-3: Public Support of Stem Cell Research in 2009. A Gallup Poll conducted in February of 2009 showed that majority of Americans (52%) supported Obama's easing Bush's restriction or lifting restrictions entirely on hESCs. (Morales, 2009)

Obama's new legislation holds a lot of promise for stem cell research. The NIH estimates the number of newly allowed hESC lines to be anywhere from 400 to 1000. These lines are vastly different from the 21 or so originally eligible for federal funding under the previous Bush administration.

The new legislation, however, is governed by guidelines created by the NIH, to ensure the hESC research complies with ethical standards. For instance, only excess embryos derived from IVF clinics are to be used to derive hESC lines. Also, the donor must provide informed consent before the embryo can be used for research. Furthermore, money cannot be used to pay or bribe individuals to donate their embryos solely for research. But despite the ethical guidelines, federal funding can be used to support hESC research, and that was welcoming news to scientists, and many supporters of hESC research. Former first lady Nancy Reagan, who rose to become a prominent supporter of stem cell research after the death of her husband, former President Ronald

Reagan, from a 10-year battle with Alzheimer's, said that she is "very grateful" that Obama has reversed the federal government's policy on embryonic stem cell research funding. "These new rules will now make it possible for scientists to move forward… We owe it to ourselves and to our children to do everything in our power to find cures for these diseases -- and soon" Reagan added (Childs and Stark, 2009).

International Stem Cell Policies

At the international level, hESCs have gathered both support and opposition. In Europe, laws on stem cell research vary widely, with the United Kingdom being one of the biggest supporters, and Germany enforcing a near total ban. In 2006, Germany, and the widely Roman Catholic Italy, strongly opposed the research, and tried to put pressure on other European countries to reject a proposal that will allow EU money to fund stem cell research in other EU countries. Alongside Germany, Austria, Poland, Slovakia, Slovenia, Lithuania, Luxembourg, and Malta strongly opposed that EU should provide money from the science budget for 2007 to 2013, to support projects in some countries if the same research is prohibited in other sister countries (Welle, 2006). In fact, Germany and Italy banned any new extractions of ES cells from human embryos. However in July of 2006, the legislative body of the EU passed legislation allowing the funding of hESC research (Welle, 2006).

Countries like United Kingdom, China, Australia, Sweden, South Korea, Singapore and Japan, are actively involved in stem cell research. As seen in **Figure-4**, the governments of these countries (dark brown in the diagram) are very permissive and flexible to the research.

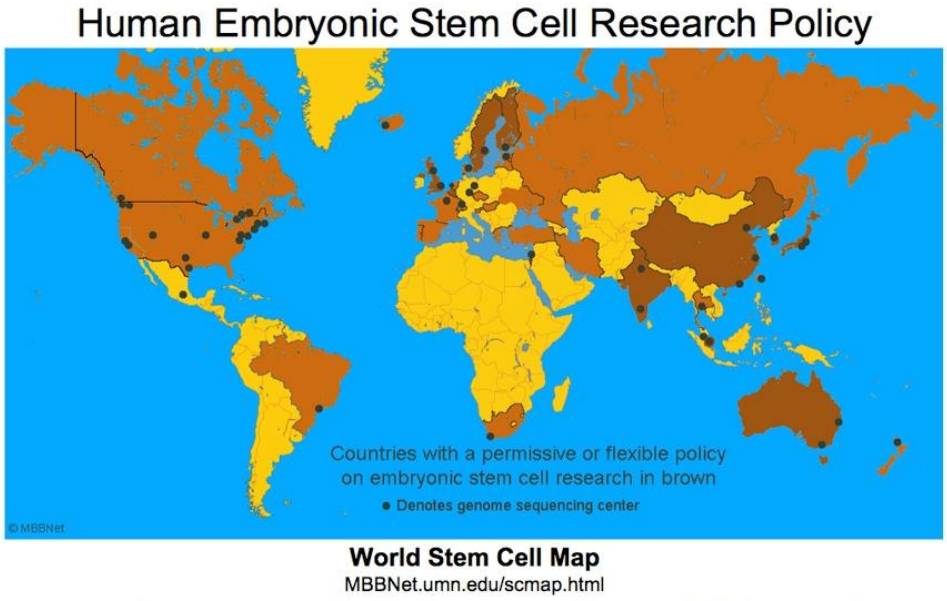

Figure-4: World Stem Cell Policies. Shown is a world map with various countries in color depending on their stem cell policies. Dark brown areas denote countries with permissive and flexible policies, allowing most forms of ES cell research. This region represents 3.8 billion people. Yellow denotes countries with no stem cell policy in place. Light brown shows countries that have moderate policies governing the research. These countries mostly allow embryonic stem cell research from IVF embryos (Hoffman, 2005).

The United Kingdom has long been a major player in bioscience and Europe's leader in stem cell research. In 2004, England became the third country in history to allow scientists to clone hESCs openly for research through somatic nuclear transfer (Ralston, 2008). In 2005, a team of British scientists was the first in the world to successfully clone blastocysts (early stage embryos). Britain became the first country to legalize cloning, allowing scientists to make cloned embryos for stem cell research. In England, scientists can destroy donated embryos for stem cell research, and can create embryos by IVF. The Government believes that stem cell research offers enormous potential to deliver new treatments for currently incurable diseases. As such, the government is working hard to promote the research, and has taken initiatives like establishing

the Human Fertilization and Embryology Authority to investigate and direct ES cell research. The government strives to make sure UK is in the forefront of stem cell research.

Sweden is also considered a leader in stem cell research. With a well-established biomedical industry, the Swedish government provides funding to a large number of stem cell researchers. In 2002, the Swedish government further authorized the creation of Europe's second stem cell bank (Ralston, 2008).

China has one of the most unrestrictive stem cell policies. In 2003, guidelines were issued by the Chinese government regulating the research because of the international criticism received, but China continues to permit researchers to conduct clinical trials in which terminally or chronically ill patients receive stem cell therapy (Ralston, 2008). Interestingly, life begins at birth according to the Chinese culture, yet they still support embryo and hESC research. Other countries such as Canada, Brazil, India, Russia, Belgium, and South Africa are also taking part in stem cell research, but with less involvement and more moderate policies.

As other countries around the world progress in the stem cell field, some scientists fear the US will fall behind unless it expands federal funding to include *therapeutic* cloning. The United States has the most potential in this field because of its leading institutions and ability to pay financially, however politics and ethics have worked against the progress of hESC research in the country. But under president Obama, the future of the country in this important field of science appears promising.

Chapter-4 Conclusions

Stem cell research, especially hESC research is a highly controversial topic, both politically and ethically. Thus, many governments around the world have enacted laws to

regulate it. In this chapter, the laws regulating embryo and hESC research in different countries, including the US and its individual states, were discussed. The chapter also explored how political views strongly influence the progress of science and discovery. Over the past several decades, hESC research was generally suppressed in the US, forcing individual states to take on duties historically performed by the federal government and NIH into their own hands, and funding private institutions to conduct the research. This situation highlights the dynamics and power of the US legislative systems as it relates to science. Although alternatives to hESCs exist, including adult stem cells and induced pluripotent cells, these cells hold less promise to mankind, as they are harder to isolate and grow. Thus the quest to purse hESC research continues, with a hope for politicians to put ideology aside in this matter. President Barack Obama took a prime step to end the 8.5 years ban on federal funding for the research under Bush, presenting a hopeful future to the US and the outside world in this area of science. As Sean Morrison, the director of the University of Michigan Center for Stem Cell Biology in Ann Arbor said "President Obama's executive order signals a new day in which science policy will be based on science… America will once again seek to be the world's engine for biomedical discovery, leading the way toward new treatments for disease" (Childs and Stark, 2009).

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PROJECT CONCLUSIONS

Stem cell research, and especially embryonic stem (ES) cell research, brings both controversy and promise. The authors of this paper, based on the research performed in this project, now provide their own personal conclusions. All three authors agree that stem cell research is extremely important, and believe funding should be increased for it. After all, some stem cell applications have already been proven to save lives in humans. With respect to embryos, one author sees that destroying an embryo should be avoided. Thus, adult stem cells (ASCs) and induced pluripotent stem (iPS) cells should be used as a replacement therapy whenever possible. The group as a whole, however, shares the opinion that excess embryos from IVF reproductive clinics should be used for ES research rather than embryos from paid donors. If women were allowed to donate their embryos for ES cell research in exchange for a monetary compensation, some women needing money might violate their own ethical beliefs and act as donors. Using money as an incentive for people to donate their embryos would compromise the science and the true meaning of the research.

As far as laws regulating embryo use, all three authors agree that the research should be governed by guidelines, ensuring that ethical boundaries are not crossed. Thus, to a large extent, we agree that the Unites States under the Obama administration currently has acceptable policies in place governing stem cell research, and tend to think the policies of England, Sweden and China go too far in allowing SCNT cloning. The current tight US guidelines on creating acceptable ES cell lines could be loosened to further stimulate ES cell research. The authors applaud US states such as New Jersey, California, and Massachusetts, on their efforts for

keeping ES cell research alive by approving state bonds to fund private institutes. These efforts, as well as others, will help promote regenerative medicine and help find answers to currently incurable human diseases. Stem cell research should be given a chance, and the promise it carries should be the driving force.