Stem Cell Research

A Science and Policy Overview

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An Introduction to Stem Cells

Stem cells are cells that have the potential to replicate themselves for indefinite periods and to divide, producing one copy of themselves and one cell of a different type (**differentiation**). In humans, stem cells have been located in the early stages of development after egg fertilization (around five to six days); the umbilical cord and placenta; and in several adult organs.

Regardless of their source all stem cells have two general properties:

- *Stem cells are capable of dividing and renewing themselves for long periods.* Unlike muscle cells, blood cells, or nerve cells — which do not replicate themselves — stem cells can divide continuously and keep their innate properties.
- *Stem cells are undifferentiated and can give rise to multiple cell-types.* Stem cells do not have any tissue-specific structures that allow them to perform specialized functions. They cannot carry molecules of oxygen through the bloodstream like red blood cells or release signals to other cells, such as permitting the body to move or speak, as nerve cells do. Although stem cells do not have any tissue-specific structures, they can give rise to differentiated cells, including red blood cells and nerve cells.

Stem cells have varying abilities to differentiate into different cell-types. One type of stem cell can give rise to any other cell-type of a given organism (for example, an embryonic stem cell). Other stem cells can only give rise to cells of a given tissue type (for example, bone marrow can produce blood stem cells) or only give rise to a few cell-types in a given tissue.

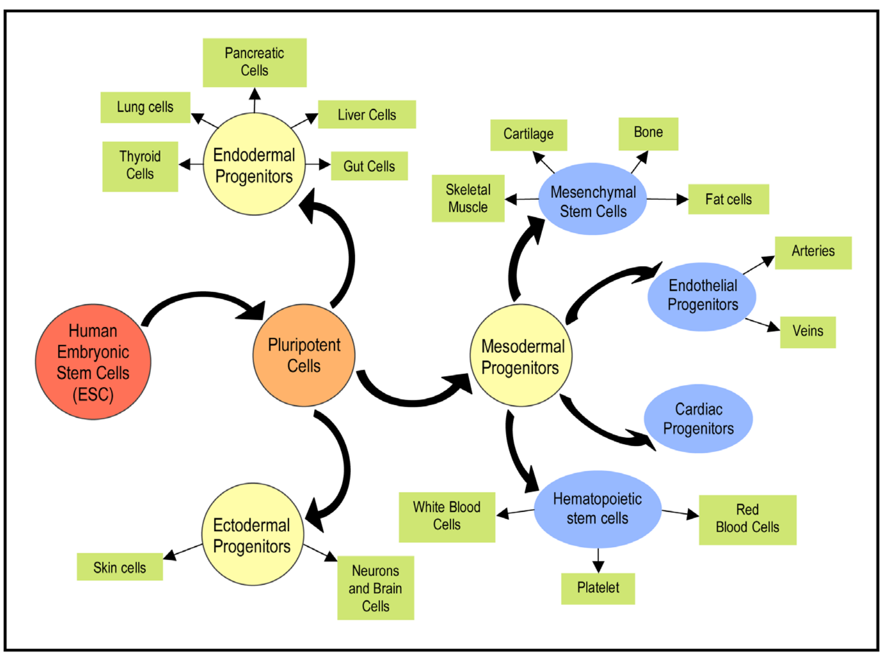


Figure 1 *The potential uses of embryonic stem cells.*

Scientists are just beginning to understand the signals in a body which can trigger cell differentiation. These signals can be created within a cell, triggered by a cell's genes, or by a neighboring cell that releases chemicals to promote differentiation in other cells. Determining what these signals are and what stem cells require to differentiate into different cell-types is a crucial research area which must be explored in order to utilize stem cells for therapies.

When cells differentiate, their abilities become more restricted. They often follow only a few prescribed pathways and can lose the capacity to replicate themselves. The ability of stem cells to replicate and remain unspecialized until they are needed is an important area of research vital to understanding human development.

Stem cells offer a new look at old problems and diseases such as burns and diabetes. Although the field is relatively new, the impact of new discoveries could profoundly change medical research and therapy. Many of these new approaches involve the use of **somatic cell nuclear transfer** (sometimes known as **therapeutic cloning**) to produce recipient-specific tissue by creating embryonic stem **cell lines**.

This new area of research has great potential, but it is not without its controversies. Many ethical dilemmas are produced with the creation and destruction of human **blastocysts** as well as the potential to clone an entire human being (**reproductive cloning**). No matter where society designates the boundary to be for this research, or whether stem cells can live up to our high expectations, a great deal can be learned through careful and thoughtful studies.

Embryonic Stem Cells

Embryonic stem cells are derived exclusively from a fertilized egg that has been grown ***in vitro*** for 5 to 6 days to form a **blastocyst**. Within a blastocyst there is a small group of about 30 cells called the **inner cell mass**, which will give rise to the hundreds of highly specialized cells needed to make up an adult organism. Embryonic stem cells are obtained from this inner cell mass. For research purposes, embryonic stem cells are produced specifically from eggs that have been fertilized *in vitro*, or in a laboratory and not inside a woman's body, or ***in vivo***. Embryonic stem cells can come from a frozen fertilized egg or an egg which is fertilized *in vitro*.

Embryonic stem cells can and do differentiate into all the specialized cells in the adult body. They could be induced to provide an unlimited source of specific and clinically important adult cells such as bone, muscle, liver, or blood cells.

Adult Stem Cells

Adult stem cells are unspecialized or undifferentiated cells found among specialized

Embryonic Human Stem Cells Have Been Grown into the Following Cell-Types:

- Smooth Muscle
- Heart Muscle
- Nerves
- Bone
- Cartilage
- Kidney
- Red and White Blood Cells
- Pancreas
- Liver
- Yolk Sac
- Lymph Nodes
- Endoderm
- Retinal (Eye) Cells

cells in an adult tissue or organ. In some adult tissues, such as in bone marrow, muscle, or brain tissue, discrete populations of adult stem cells generate replacements for cells that are lost through disease, injury, or normal wear and tear. Adult stem cells are thought to reside in an area of each tissue where they may remain **quiescent**, or nondividing, for many years until they are activated by disease or tissue injury. Where they are found, adult stem cells consist of a very small population of cells within each tissue.

Some adult stem cells retain the ability to form into specialized tissues other than the one from which they originated. For example, blood (**hematopoietic**) cells have not been proven to differentiate into nerve, skeletal muscle, cardiac muscle, or liver cells. There is some evidence that brain stem cells can differentiate into blood or skeletal muscle cells. However, adult stem cells have a limited number of tissues they can differentiate into and do not have the same potential as embryonic stem cells to become any cell-type.

The environment that adult stem cells grow in has an important, but poorly understood, effect on their fate. The relationship between the adult stem cell environment and its ability to differentiate into other cell-types has also not been fully explained.

Distinctions between Embryonic and Adult Stem Cells

Most importantly, there is a divergence between adult and embryonic stem cells and the type of differentiated cells they can become. While embryonic stem cells can be induced to differentiate into any cell-type, adult stem cells cannot. Most adult cells can only differentiate into the types of cells found in their environment or in the particular tissue or organ where they reside. Therefore in many vital organs, adults do not have the stem cells necessary to regenerate damaged areas; thus scar tissue will develop instead.

Adult Human Stem Cells Have Been Grown into the Following Cell-Types:

- Red and White Blood Cells
- Skin
- Fat
- Smooth Muscle
- Heart Muscle
- Skeletal Muscle
- Liver
- Digestive Tract
- Nerves
- Cartilage
- Pancreas

Another key difference between embryonic and adult stem cells is the volume of cells one can isolate and grow *in vitro*. Large numbers of embryonic stem cells can be grown *in vitro* from a single blastocyst. On the contrary, adult stem cells are rare and methods of growing them still need to be perfected. In addition, due to their limited numbers, it is difficult to isolate a group of adult stem cells in pure form, without having them contaminated with differentiated cells.

Potential Uses of Stem Cells

Stem Cells

While stem cell research is in its infancy and many of its proposed uses are hypothetical, the research has generated excitement among many scientists for its potential. One of the vital components of ongoing work is understanding the very nature of these cells; that is, to determine the conditions necessary to maintain undifferentiated stem cells as well as differentiating them along specific pathways. In order to truly determine whether or not these cells can be used therapeutically, more research must be conducted to understand the nature of the cells.

Although we are only beginning to discover what stem cells are capable of doing, scientists have proposed several potential uses.

Abnormal Cell Division. Many serious medical conditions, such as cancer and birth defects, are due to abnormal cell divisions or the inability of cells to turn themselves on and off properly. Having a better understanding of stem cells and their genetic and molecular controls would yield information about diseases and reveal potential strategies for therapies.

Drug Testing. Stem cells could be used to test new drugs or medications by differentiating them to the particular cell-types that the drugs are targeting. This would offer a shortcut for scientists to sort out chemicals that can be used to treat diseases. By testing new drugs on stem cell lines, we could perform rapid screening of hundreds of thousands of chemicals that now are tested by more time-consuming processes. This could also potentially decrease the time that it takes to get a drug to market.

Cell-Based Therapies. Stem cells could be used for cell-based therapies. Stem cells could be directed to differentiate to a specific cell-type which could be used as a renewable source of replacement cells and tissues. In order to be useful for cell-based therapies, stem cells must be made to do the following:

- *Differentiate into desired cell-types.* It is necessary for stem cell techniques to be improved until they can consistently and efficiently differentiate into a specific cell or type of cells without contamination by undifferentiated or improperly differentiated cells.
- *Proliferate extensively and generate sufficient quantities of tissue.* The protocols for differentiating stem cells need to be refined so that large quantities of tissue can be produced in a relatively efficient manner.
- *Survive in the recipient after the transplant.* Scientists must determine that the cells are healthy and viable after transplantation. They also should establish that the stem cells are localized to the correct tissue in the recipient.
- *Function appropriately for the duration of the recipient's life.* Not only do the cells need to be localized and survive, but they must also behave like the original cells. Currently, there is not sufficient data showing that stem cells are functional in

Conditions that Stem Cell Research Could Potentially Help:

- Parkinson's
- Alzheimers
- Spinal Cord Injury
- Stroke
- Burns
- Heart Disease
- Diabetes
- Osteoarthritis
- Rheumatoid Arthritis
- Birth Defects
- Infertility
- Pregnancy Loss
- Leukemia
- Brain Cancer
- Muscular Dystrophy
- Sickle Cell Anemia
- Brain Trauma/Damage
- Liver Disease
- Metabolic Disorders
- Deafness
- Macular Degeneration
- Retinitis Pigmentosa
- Organ Donation

their new environment when they are transplanted into organs. For cell-based therapies to be successful, the new cells need to function correctly and interact properly with the original tissue.

- *Avoid harming the patient in any way.* One concern about using undifferentiated cells or stem cells is the risk of the stem cells having genetic abnormalities which could cause them to be cancerous or to be rejected due to tissue immune incompatibility. Adequate testing is necessary to make sure the cells used are healthy.

Embryonic Stem Cells

One of the most promising uses for embryonic stem cells is the study of the complex events that occur during human development. The earliest stages of human development have previously been difficult or impossible to study. By using embryonic stem cells, these studies can be performed with the goal of preventing or treating birth defects, infertility, and pregnancy loss.

The use of embryonic stem cells can also help scientists identify how undifferentiated cells become differentiated. Since these cells have the ability to become any type of cell in the adult body, they have a larger potential for medically viable tissues which can be derived and used in cell-based therapies.

Cloning and Alternatives

Therapeutic Cloning

Somatic cell nuclear transfer (SCNT) is the process of removing the genetic material (**nucleus**) of an unfertilized egg and replacing it with the genetic material of a normal cell. Afterwards, the egg is then activated and allowed to grow. After it is allowed to grow into a blastocyst, embryonic stem cells are obtained from the inner cell mass. These embryonic stem cells can then be induced to become other differentiated cell-types.

Much of the promise for embryonic stem cells lies in the potential of deriving or creating cell lines which are specific to a person. This

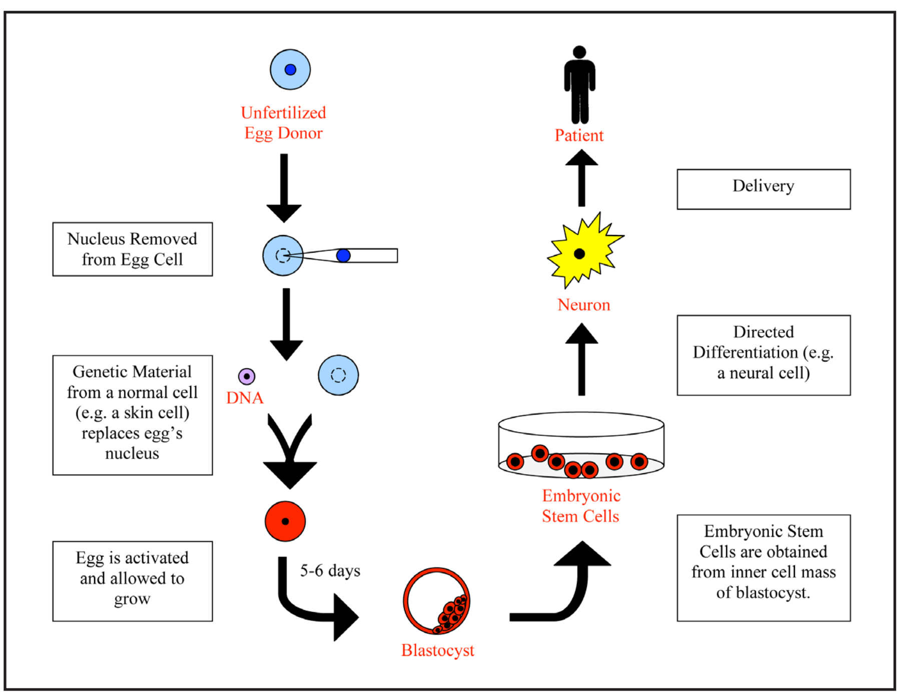


Figure 2 *Somatic nuclear cell transfer*

technique can be used to create cell lines and study the development of different diseases (sometimes called therapeutic cloning). For instance, by using a skin cell from a patient suffering with Parkinson's disease one could create a cell line that would show the researcher how the cell progressed from a normal to a diseased state. Not only could scientists study specific genetic diseases, but they could also create tissues that are compatible with the original donor.

Further, this technique can also be used to create tissues that are recipient-specific. In organ and tissue transplantation, a great concern is the rejection of transplanted tissue by the recipient's immune system. If new cell lines were created to be identical to the recipient, this would no longer be a problem

Reproductive Cloning

Reproductive cloning is the process of creating a human being that is the exact genetic copy of the donor. It occurs when an egg undergoes somatic cell nuclear transfer and the resulting cell is allowed to grow to an infant. Attempts at reproductive cloning have been error-prone and inefficient, resulting in the failure of most clones to develop. The most famous clone, Dolly (a sheep), was only created after multiple attempts and failures and then lived a shortened life (Wilmut et al, 1997).

Induced Pluripotent Stem Cells

Another option for creating stem cells without using human eggs is deprogramming normal cells to become pluripotent cells. These are known as induced pluripotent stem (iPS) cells.

The first set of experiments using iPS cells was performed in mice in 2006. When four specific genes are activated in a normal cell (such as a skin cell), the cell becomes deprogrammed and regains its ability to differentiate into many different types of tissue and to divide indefinitely. Scientists have been able to create entire mice using only iPS cells.

In 2007, two separate research teams successfully applied this technology to human cells. Each group took human skin cells and activated four genes (although each group activated a different set of genes), creating iPS cells.

However, this innovative procedure has problematic aspects: one of the necessary genes activated is a cancer-inducing gene and contributed to cancer in up to 20 percent of the mice studied. The genes were also introduced into skin cells by way of a virus, which has the potential to cause adverse effects. The method used also involved the insertion of the genes into the genome randomly, which could be another cause of the cancers seen in test subjects.

In 2008, scientists began the implementation of a new method which bypassed the viral vectors previously utilized for the introduction of the genes necessary to create the iPS cells. Instead, these scientists utilized a number of chemical combinations.

Overall, this procedure, as it applies to humans, still has a number of research issues to overcome. However, if this procedure generates cells to be placed into the human body, the issue of immune rejection would be eliminated because the stem cells are genetically identical to the donor cells. Also many ethical qualms regarding stem cell research could be resolved, since this procedure does not involve human embryos or eggs.

Case Study: Juvenile Diabetes and Stem Cell Research

Juvenile diabetes, also known as type 1 diabetes, is essentially an **autoimmune** disease where one's own body starts attacking itself. In juvenile diabetes the body specifically destroys a pancreas cell, the **ß-cell**, which produces **insulin**. Insulin is an important hormone that balances blood sugar levels. Unregulated sugar levels in the blood can lead to severe problems such as kidney failure, blindness, stroke, and even death. Patients with juvenile diabetes are required to take multiple injections of insulin daily or have a continuous infusion of insulin through a pump just to survive. Also, they must constantly monitor their food intake and daily activities.

Scientists have been working for years to find a cure and are extremely optimistic about the potential use of stem cells to replace destroyed ß-cells. In a recently published study using mice, Harvard researchers determined that new ß-cells in the pancreas are formed through the replication of pre-existing ß-cells, rather than adult stem cells creating new ß-cells. These are the very cells being attacked and therefore their numbers are limited. This result means that in order to cure juvenile diabetes, scientists must rely on another source of ß-cells, such as embryonic stem cells, to generate new ß-cells.

In February 1997, Dr. Ian Wilmut announced the creation of the first cloned mammal. The report, published in the science journal *Nature*, described a lamb, "Dolly," which was cloned using somatic cell nuclear transfer (SCNT). This landmark paper and the media attention it received created an immediate reaction from the public and politicians in Washington, D.C., who were concerned about the potential cloning of humans using this technique. Since Dolly's creation, congressional leaders have been trying to find a way to prevent human cloning and other allegedly unethical medical procedures while still allowing medical research to proceed unhindered.

In late 1998, the issue was further complicated by the announcement from researchers at the University of Wisconsin-Madison, led by Dr. James Thomson, who derived the first human embryonic stem cells from blastocysts. This marked the beginning of a new area of medical science, human embryonic stem cell research. With this new breakthrough, the issue of human cloning became considerably more complex, since SCNT was now linked to potential disease-curing research.

Since then, with each congressional session, a new crop of conflicting bills arise from both the House and the Senate. However, in 2009, President Barack Obama signed an executive order expanding funding for human embryonic stem cell research and asked Congress to pass legislation explicitly legalizing the funding of embryonic stem cell research. Polls show that while a majority of Americans approve embryonic stem cell research, the vast majority disapprove of research which could produce a cloned human (79 percent in a 2005 poll by Research!America). This debate over reproductive cloning as well as other aspects of stem cell research still resonate in Congress and generate the current predicament where lawmakers have yet to address embryonic stem cell research as well as other implications of this research.

Pre-"Dolly" Regulation

In the 1970s, rules were developed to govern the federal funding of research on human embryos for *in vitro* fertilization (IVF). The rules specified that all federally funded research on human embryos would need to be approved by a congressionally appointed ethics advisory board. Although the board met once, it was dissolved in 1980 without ever federally funding embryonic research. In 1993, this rule was rescinded, but the Dickey Amendment, a **Department of Health and Human Services** (DHHS) 1996 appropriation rider, subsequently banned any federal funding of human embryo research, and each year this amendment has been attached to the appropriation bill for the DHHS. Since that time, no federal funds have been allowed for embryo (and therefore embryonic stem cell) research, but private funding of research on embryos has been allowed and is completely unregulated.

Post-"Dolly" Debate

In February 1997, after the public announcement about "Dolly," President Clinton charged the

National Bioethics Advisory Council (NBAC) to study the issue of human cloning. In June of that year, NBAC released a report which determined that reproductive cloning was immoral and requested that a moratorium should be established until subsequent laws prohibiting it were passed (with a sunset period of 3–5 years). The members also suggested that the law be written so it would not interfere with biomedical research. Taking their suggestions, Clinton offered a legislative proposal to bar anyone (either federally or privately funded) from attempting to clone a human through SCNT for five years. President Clinton's proposal was announced after several bills in the House and Senate had already been introduced. However, because many feared that Congress might accidentally bar valid research, the majority needed to pass these bills was never obtained, and thus no legislation limiting such cloning was ever successfully passed into law.

In November 1998, after Dr. Thomson announced the creation of the first human embryonic stem cell line, President Clinton asked NBAC to specifically address human embryonic stem cell research, which had not been discussed in 1997. In 1999, the NBAC recommended that federal funding should be used to support both the research and creation of human embryonic stem cells. They also suggested amending the ban on embryo research (the Dickey Amendment) to allow the derivation and use of embryonic stem cells.

However, before the results of the NBAC deliberations were announced, the **National Institutes of Health** (NIH), specifically the legal council for the DHHS, determined that federal law (the Dickey Amendment) prohibited the use of federal funds to create human embryonic stem cell lines, but they did believe that it was legal to fund research on already existing lines. Private sources were never barred from deriving their own human embryonic stem cell lines and were actively pursuing this area of research.

The NIH released guidelines for the federal funding of human embryonic stem cell research for public comment in 1999, followed by an updated version in 2000 in the *Federal Register*. Before NIH was able to grant money in response to research proposals, a new administration (President George W. Bush) took office and the previous rulings by the DHHS and NIH were set aside.

Meanwhile in the Senate, the Specter–Harkin bill (S.2015) was introduced as the Stem Cell Research Act of 2000. It called for the federal funding of the derivation and use of human embryonic stem cells from spare donated embryos (IVF), as long as the research did not lead to "reproductive cloning of a human being." This marked the first of many bi-partisan bills that Congress would see on this issue. The Specter–Harkin bill, like many future bills, was not passed into law.

When President Bush took office, one of his first actions was to temporarily stop all federal funding of human embryonic stem cell research (no grant had been given) while his administration considered their actions. On August 9, 2001, after several months of deliberation, President Bush announced that he would allow the federal funding of the research of human embryonic stem cells, but only those that had been derived before the date of the announcement could be used. Thus, no new embryonic stem cells could be created with federal funds, nor could federal funds be used to do research on new lines created after the August 9, 2001, deadline. NIH estimated at the time that there were as many as 60 to 75 cell lines available for research. However, since that time, NIH revised its numbers downward to only 21 lines, which qualified for funding under the Bush policy.

In November 2001, President Bush established the **President's Council on Bioethics** (PCB), a group of experts (similar the NBAC), to address

Stem Cell Research Enhancement Act

The "Stem Cell Research Enhancement Act" is a bill promoting embryonic stem cell research from the U.S. Congress. It originated in the U.S. House of Representatives by Representatives Castle (R-NH) and DeGette (D-CO) and was passed in the U.S. House of Representatives in 2005 and 2007 and in the U.S. Senate in 2006 and 2007. Both times the bill was ultimately vetoed by President George W. Bush.

The bill proposes an amendment to the Public Health Services Act to allow left-over IVF eggs to be donated for stem cell research (stipulating that the donated eggs were given with informed consent and without any financial inducements). The bill also specifically authorizes federal funding of research on human embryonic stem cells regardless of the date they were derived. All lines used must be from donated eggs in excess from IVF clinics.

This bill is expected to pass in 2009 under the Obama administration.

the issues of human cloning, embryonic stem cell research, and other bioethical issues. In Congress, new bills were introduced in the 109th Congress, and the Weldon-Stupak bill was passed in the House in 2001 and 2003 to ban all forms of cloning and the use of SCNT, but neither bill passed in the Senate. Almost every year we saw each political side introduce their version of a law which would outlaw all human cloning or only reproductive cloning and either outlaw or permit the use of embryonic stem cells, but nothing has been signed into law.

Perhaps the most interesting part of the congressional debate was the fact that views on the topic do not necessarily follow traditional party lines or a person's opinion on abortion or right to life. This new debate produced the most unlikely bipartisan partnerships and has resulted in a deadlock in Congress, which has sharply constrained federally funded research on embryonic stem cells and human cloning. At the same time, the deadlock has virtually left the privately funded research involving embryonic stem cells and human cloning completely unregulated.

With the return of President Bush to office in 2005, the possibility for changing the current federal policy seemed unlikely. However, in May 2005, the U.S. House of Representatives passed the Stem Cell Research Enhancement Act, perhaps the most significant legislative advance in the support of stem cell research. Its passage was the result of an initiative from the leaders in both parties. The bill amends the Public Health Service Act to provide for stem cell research by stating that cells donated from excess supplies from IVF clinics are viable for use. It stipulates that the donated eggs were given with informed consent and without any financial inducements. The bill goes on to say that reports of research carried out under these guidelines should be presented each fiscal year. The Stem Cell Research Enhancement Act passed in the U.S. Senate a year later in July 2006. As he promised in May 2005, President Bush vetoed the bill on July 19, 2006 (the first use of the presidential

Bush (2001) vs Obama (2009) Stem Cell Policies

Policies	Bush Administration (2001)	Obama Administration (2009)
Funds ESC research	Yes, if derived before Aug. 9, 2001	Yes
Funds therapeutic cloning	No	No
Funds reproductive cloning	No	No
Funds adult stem cells	Yes	Yes
Consent required	Yes, not strictly enforced	Yes, strictly enforced
Donated embryos only	Yes	Yes
Dickey Amendment	Yes	Yes
Guidelines	Yes, President's Council on Bioethics	Yes, NIH 2009 Guidelines

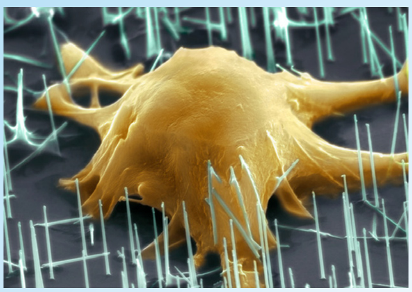
veto by Bush), and Congress was unable to override it. A similar bill was passed and vetoed in 2007.

With or without the expansion of federal funding, some states began to pick up the reins by passing their own laws related to embryonic stem cell research (see page 15, "State Cloning Legislation"). The largest initiative was passed in California. In November 2004, Californians (with 59 percent of the vote) approved Proposition 71, or the California Stem Cell Research and Cures Initiative, which called for the creation of a California Institute for Regenerative Medicine (CIRM) and authorized $3 billion of state funds to support the effort over the next five years. This proposal also established the right to conduct embryonic stem cell research in California, but prohibited reproductive cloning. President Bush's policy limited federal funding, but did not make the research itself illegal. Therefore, the states were able to determine how they wished to regulate and fund research using state funds. CIRM supported embryonic stem cell and adult stem cell research (regardless of the date the cells were generated) to create new cell lines, and to use SCNT to create cell lines with specific genes. Other states followed the California model in their own way. Many funded stem cell research, including Connecticut, Illinois, Maryland, Massachusetts, Missouri, New Jersey, New York, Oklahoma, Washington, and Wisconsin.

After assuming office, President Barack H. Obama signed an executive order on March 9, 2009, that overturned the previous administration's policy—allowing federal funding on research utilizing human embryonic stem cells regardless of the date they were created. President Obama then assigned NIH with the task of developing guidelines, which they released on July 7, 2009. The new NIH guidelines for human embryonic stem cell research increased the number of embryonic stem cell lines available for federal funding, but strictly enforced the informed consent process (see box 2 for a more detailed description of the NIH guidelines).

Summary

The debates on stem cell research essentially started in 1997, after the first mammal, "Dolly," was cloned. Through the past 12 years, the U.S. government has only been able to regulate the stem cell research conducted with federal funds. While the NIH released guidelines in 2009 that encouraged an ethical approach to stem cell research, it still failed to address the research that is taking place with private and other nonfederal funds. Congress has yet to pass legislation to specifically oversee the research, leaving the question of regulation of this research unresolved. Whether we should fund embryonic stem cell research and therapeutic cloning and how to regulate the current research done with private funds are questions U.S. lawmakers still need to address.



National Institutes of Health 2009 Guidelines

President Obama, in accordance with the March 9, 2009 Stem Cell Executive Order, assigned the National Institutes of Health with the task of creating ethical guidelines and requirements for federally funded stem cell research. On April 23, 2009, the NIH released a preliminary draft and allowed for public input. On July 7, 2009, the fully revised "2009 Guidelines on Human Stem Cell Research" were put into effect, allowing researchers to apply for federal funds towards embryonic stem cell research derived at any date.

Major criteria for funding from the NIH guidelines:

- Must use excess *in vitro* fertilization (IVF) embryos created with a reproductive intent.
- Informed, voluntary, and written consent must be obtained.
- Embryos must be donated without monetary involvement.
- Clarifies Dickey Amendment — No federal funding can be allotted towards research that creates a human embryo for research purposes or destroys a human embryo (human cloning).
- No research using cells from embryos created for research purposes will be funded.
- Created the Working Group of the Advisory Committee to the Director (ACD) to rule on special cases.

Above: Color-enhanced electron microscopic image of mouse embryonic stem cells growing on a bed of silicon nanotubes. The image was taken in the lab of Bruce Conklin at the Gladstone Institute for Cardiovascular Medicine.

Stem Cell Research

State Cloning Legislation

While the United States has not passed any federal legislation concerning embryonic stem cell research and human cloning, individual states have started passing their own laws. These laws vary greatly in policy stance and attempt to simultaneously balance ethical boundaries with the pursuit of science. Specific laws address the legality of human cloning, therapeutic cloning (SCNT), embryonic stem cells, as well as the funding of such pursuits. For sake of simplicity, states have been grouped into four categories: permissive (green), moderate (yellow), restrictive (red), and undecided (gray).

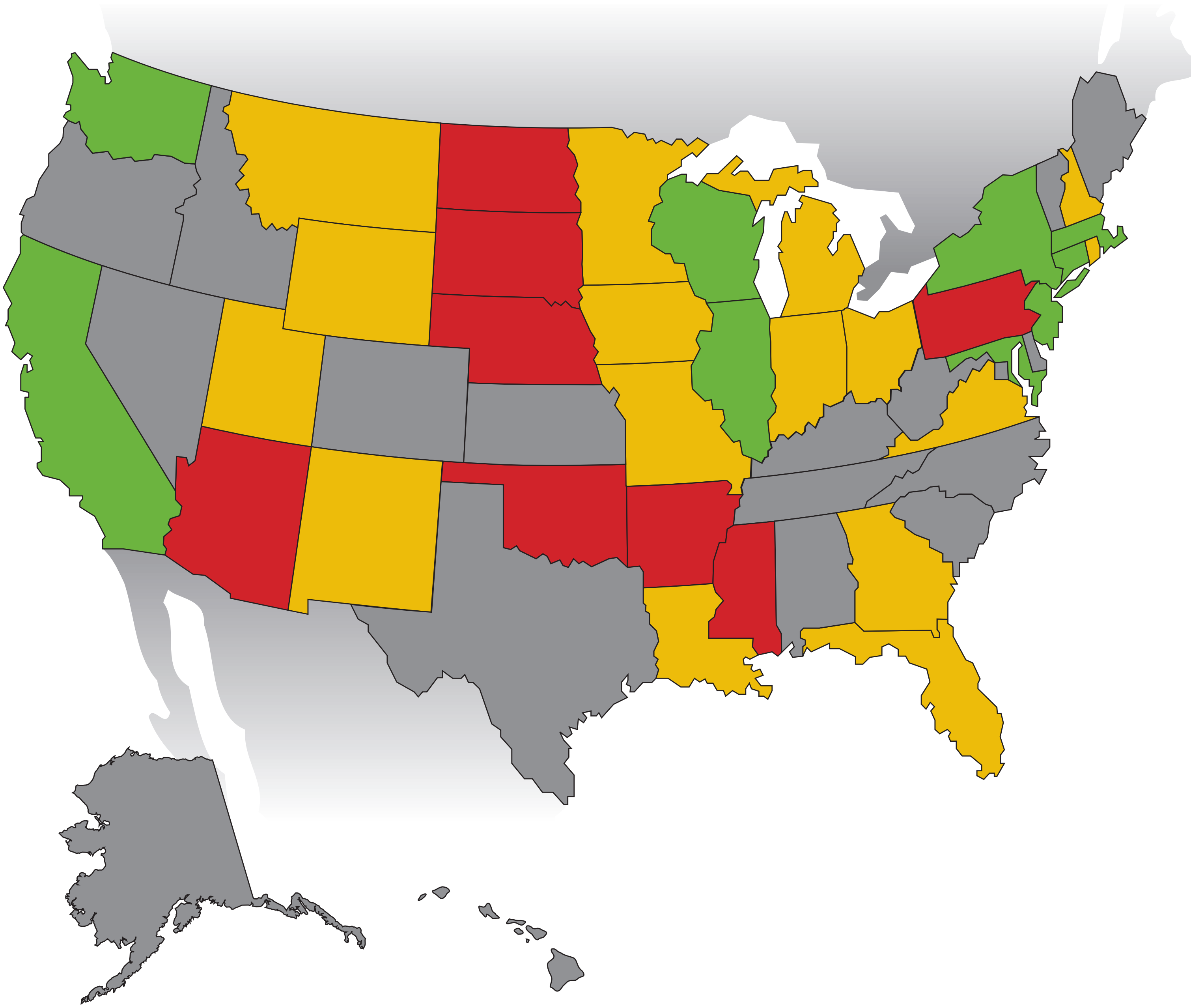
Out of the 50 states in the United States (including the District of Colombia), 33 have some legislation in effect that addresses stem cell research. Of that 33, 17 specifically prohibit reproductive cloning, 14 ban therapeutic cloning, and 18 preclude embryonic stem cell research. On the contrary, 14 states have appropriated state funding towards some form of stem cell research.

Those marked as green indicate a state "permissive" towards stem cell research through legislative actions which have specifically legalized therapeutic cloning and/or embryonic stem cell research, often times funding such research. These states are often characterized by laws which block reproductive cloning.

Those marked as yellow indicate a state with a "moderate" policy towards stem cell research through legislation, which are sometimes vague or uncertain. These states are often characterized by laws which only address one part of an extremely complex issue making them difficult to classify and set unclear boundaries for scientists and politicians to decipher. In some cases, states outlawed one type of stem cell research while directly financing another as in the cases of Indiana, Ohio, and Virginia, which outlawed embryonic stem cell research but funded adult stem cell research. Virginia fails to define "human being" so it is uncertain whether or not therapeutic cloning (SCNT) is legal or banned. Other policies include measures that complicate the process by which scientists obtain the embryos needed for research such as Wyoming who bans sale, donation, or distribution of an embryo while South Dakota and Rhode Island prohibit the sale of an embryo.

Those marked as red indicate a state "restrictive" towards stem cell research. This includes legislation which severely blocks further stem cell research via bans on reproductive cloning, therapeutic cloning, and/or embryonic stem cell research. These states often prohibit state funding towards any embryonic stem cell related study.

Those marked as gray indicate a state "undecided" towards stem cell research. These states have little or no legislation on stem cell research and/or therapeutic cloning, but often bills are pending for and against the research.



Restrictive policies which mostly ban embryonic stem cell research

Moderate policies which may ban some but not all research

Permissive policies which ban only reproductive cloning

Undecided — no legislation

State Cloning Laws

State	Has legislation that restricts reproductive cloning	Has legislation that restricts therapeutic cloning (SCNT)	Has legislation that restricts ESC research	Has legislation which funds stem cell research	Color
Alabama	N	N	N	N	Gray
Alaska	N	N	N	N	Gray
Arizona	Y	Y	Y	N	Red
Arkansas	Y	Y	Y	N	Red
California*	Y	N	N	Y	Green
Colorado	N	N	N	N	Gray
Connecticut*	Y	N	N	Y	Green
Delaware	N	N	N	N	Gray
District of Colombia	N	N	N	N	Gray
Florida	Y	Y	N	Y	Yellow
Georgia	Y	N	N	N	Yellow
Hawaii	N	N	N	N	Gray
Idaho	N	N	N	N	Gray
Illinois*	Y	N	N	Y	Green
Indiana	Y	Y	Y	Y	Yellow
Iowa*	Y	Y	N	N	Yellow
Kansas	N	N	N	N	Gray
Kentucky	N	N	N	N	Gray
Louisiana	N	N	Y	N	Yellow
Maine	N	N	Y	N	Gray
Maryland*	Y	N	N	Y	Green
Massachusetts*	Y	N	N	Y	Green
Michigan	Y	Y	N	N	Yellow
Minnesota	N	N	Y	N	Yellow
Mississippi	N	Y	N	N	Red
Missouri	Y	N	N	N	Yellow
Montana	N	Y	N	N	Yellow
Nebraska	N	Y	Y	N	Red
Nevada	N	N	N	N	Gray
New Hampshire	N	N	Y	N	Yellow
New Jersey*	Y	N	N	Y	Green
New Mexico	N	N	Y	N	Yellow
New York*	N	N	N	Y	Green
North Carolina	N	N	N	N	Gray
North Dakota	Y	Y	Y	N	Red
Ohio	N	Y	Y	Y	Yellow
Oklahoma	N	N	Y	N	Red
Oregon	N	N	N	N	Gray
Pennsylvania	N	Y	Y	N	Red
Rhode Island	N	N	Y	N	Yellow
South Carolina	N	N	N	N	Gray
South Dakota	Y	Y	Y	N	Red
Tennessee	N	N	N	N	Gray
Texas	N	N	N	N	Gray
Utah	N	N	Y	N	Yellow
Vermont	N	N	N	N	Gray
Virginia**	Y	Y	Y	Y	Yellow
Washington	N	N	N	Y	Green
West Virginia	N	N	N	N	Gray
Wisconsin	N	N	N	Y	Green
Wyoming	N	N	Y	N	Yellow

* State has enacted legislation which explicitly allows for embryonic stem cell research.
** State fails to define "human being" so legislation is unclear.

Note: Many factors (not all are listed) are input to determine the color of each state.

Stem Cell Research
World Research Policies

The information in this section is provided to illustrate the diversity of approaches various parts of the world are taking with regard to regulation of human cloning and embryonic stem cell research. This brief summary is based on a review of relevant literature and Web sites and should be considered preliminary.

World policies on human or reproductive cloning range from complete prohibition to no policies on record. More than 50 countries, including France, Germany, and the Russian Federation, have banned human cloning altogether. Over twenty-five countries, such as Japan, the United Kingdom, and Israel, have banned human reproductive cloning, but permit therapeutic cloning. A few countries such as Hungary and Mexico, only specifically prohibit reproductive cloning and have no legislation enacted for embryonic stem cell research or therapeutic cloning. Many other countries, similar to the United States, have yet to pass any official legislation concerning human cloning allowing all types of stem cell and cloning research to occur.

In addition to countries developing their own policies, several international organizations, including the United Nations, the Council of Europe, and the European Union, have published human cloning policies and recommendations, which are described below. The Vatican City, a small nation-state that houses the Catholic Church and influences over 1 billion members around the world, has issued a firm opinion opposing all research using embryos. Other groups including the African Union and the Arab Leagues have discussed the issue, but have yet to release a formal declaration on stem cell research. Furthermore, the International Society for Stem Cell Research (ISSCR) and a group led by Johns Hopkins Phoebe R. Berman Bioethics Institute, known as the Hinxton Group, have released principles for international human embryonic stem cell collaboration and cooperation.

United Nations

On March 8, 2005, the United Nations General Assembly adopted the nonbinding "Declaration on Human Cloning," by which member states were called on to adopt "all measures necessary to prohibit all forms of human cloning inasmuch as they are incompatible with human dignity and the protection of human life." The vote was 84 in favor (including United States, Germany, and Italy), 34 against (including United Kingdom, South Korea, and Brazil), 37 abstaining (including South Africa and Israel) and 35 were absent. This declaration is arguably weakened by the fact that it was not even passed by a majority of the U.N. membership.

Many countries, in formal explanations of their votes, expressed disappointment that there was no consensus on the language of the declaration and said that it was regrettable that it did not cover the well-known differences between reproductive cloning and therapeutic cloning (somatic cell nuclear transfer). The original mandate to the Legal Committee was to elaborate on the issue in an international treaty against human reproductive cloning. Instead, text of the declaration blurred the line separating reproductive and therapeutic cloning.

Council of Europe

The Council of Europe is an international organization of 46 countries in Europe which was established in 1949. The council was set up to defend human rights and democracy, develop continent-wide agreements to standardize social and legal practices, and promote European interests. Membership to the council is open to all European democracies, which accept the principle of the rule of law and guarantee fundamental human rights and freedoms to their citizens.

The Council of Europe has several conventions that can be applied to human embryonic stem cell research and human cloning. The council's 1997 Convention on Human Rights with Regard to Biomedicine highlights the "need to respect the human being both as an individual and as a member of the human species." The protocol on cloning states that "any intervention seeking to create a human being genetically identical to another human being, whether living or dead is prohibited." While this specifically bans reproductive cloning it does not necessarily ban therapeutic cloning. The council left the interpretation of "human being" to national Parliaments, allowing therapeutic cloning where it is accepted. In several European countries without specific stem cell or cloning legislation (Bulgaria, Croatia, Cyrus, Moldova, Romania, and San Marino) this convention is interpreted to mean that they allow human embryonic stem cell cloning, but ban both reproductive and therapeutic cloning.

European Union

The European Union is an intergovernmental and supranational union comprised of 25 member states from Europe. It was established in 1950 by six countries (Belgium, France, Germany, Italy, Luxembourg, and the Netherlands) and dealt with economic and trade issues. It now has an additional 19 member states (Denmark, Ireland, United Kingdom, Greece, Portugal, Spain, Austria, Finland, Sweden, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia) for a total of approximately 450 million people and deals with a wide range of issues including health, the environment, and international peace and stability.

The European Union supports funding embryonic stem cell research (where permitted), but has banned the funding of human cloning. There is no legal ban on therapeutic cloning, but the European Union will not fund research using SCNT to create embryos. It allows for countries to determine within their border what embryonic stem cell research can be funded allowing that it is carefully regulated, peer reviewed, scientifically sound, directed towards sustainable goals, and ethically sound.

The Vatican

In 2008, the Vatican issued "Instruction *Dignitas Personae* on certain Bioethical Questions," which further clarifies the 1987 *Donum Vitae* pertaining to the Church's bioethical views on stem cell research. The document reiterated that life begins at conception, and therefore the Catholic Church opposes all forms of embryonic stem cell research. The Vatican does support adult stem cell use as it does not involve a human life as defined by Catholicism. This policy impacts an estimated 1 billion people around the world.

World Cloning Laws

State	ESC Research banned/heavily restricted	Reproductive cloning prohibited	Therapeutic cloning prohibited
Argentina		X	X
Australia*		X	
Austria	X	X	X
Belgium*		X	
Brazil		X	X
Canada		X	X
Chile		X	X
China		X	
Colombia		X	
Costa Rica	X	X	X
Czech Republic		X	
Denmark		X	
Ecuador	X	X	X
Egypt		X	
El Salvador	X	X	X
Estonia		X	X
Finland		X	
France		X	X
Georgia		X	X
Germany	X	X	X
Greece		X	X
Hong Kong		X	X
Hungary		X	
Iceland		X	X
India		X	
Iran			
Ireland	X	X	X
Israel		X	
Italy	X	X	X
Japan		X	
Latvia		X	X
Lithuania	X	X	X
Mexico		X	
Netherlands		X	X
New Zealand		X	
Norway	X	X	X
Panama		X	X
Peru		X	X
Poland	X	X	
Portugal		X	X
Russian Federation		X	
Saudi Arabia*			
Singapore*	X	X	
Slovakia	X	X	X
Slovenia		X	X
South Africa		X	X
South Korea		X	
Spain*		X	
Sweden*		X	
Switzerland		X	X
Taiwan		X	X
Thailand		X	
Trinidad & Tobago	X	X	X
Tunisia	X	X	X
Turkey		X	
Ukraine		X	
United Kingdom*		X	
United States			
Uruguay		X	
Vietnam		X	X

* Specifically legalizes therapeutic cloning.

North America

Canada

- Reproductive cloning and therapeutic cloning (SCNT) are prohibited by the Assisted Human Reproduction Act (2004).
- Embryonic stem cell research is legal, but limited to leftover IVF embryos.

Costa Rica

- Embryonic stem cell research, therapeutic cloning, and reproductive cloning are banned.
- Any manipulation of an embryo's genetic code is prohibited, as well as any experimentation on the embryo (1995/1998).

Mexico

- Reproductive cloning is prohibited by the General Health Law (May 1997).

Panama

- Prohibits research as well as funding of all forms of cloning (reproductive and therapeutic) through Law No. 3 Human Cloning Prohibition (2004).
- Embryonic stem cell research is not specifically banned.

El Salvador

- Embryonic stem cell research as well as therapeutic and reproductive cloning is banned.

Trinidad and Tobago

- Embryonic stem cell research as well as therapeutic and reproductive cloning is banned.

United States

- Officially, embryonic stem cell research, therapeutic cloning, and reproductive cloning are legal, as there is currently no federal regulation or policies overseeing these practices.
- In 2009, President Obama issued an executive order, which overturned the Bush administration's ban on federal funding towards stem cell lines derived after August 9, 2001. The Obama administration is expected to increase the federal funding, now open to all stem cell lines, in accordance with new NIH guidelines.
- Some individual states have made their own laws against reproductive and/or therapeutic cloning. (See page 16, "State Cloning Legislation.")

South America

Argentina

- Embryonic stem cell research is permitted, but all forms of cloning (reproductive and therapeutic) are banned.
- The law specifically states that experiments concerning the cloning of human cells in order to generate human beings is prohibited.

Brazil

- Embryonic stem cell research is allowed on IVF embryos that have been frozen for at least three years.
- Therapeutic cloning and reproductive cloning are banned (Bio-Safety Law, March 24, 2005).

Chile

- Embryonic stem cell research is not specifically prohibited, but therapeutic and reproductive cloning and the funding of such activities are.
- The law states that the cloning of human beings and interventions which result in the creation of a human being genetically identical to another are prohibited.

Colombia

- Embryonic stem cell research and therapeutic cloning are permitted, but reproductive cloning is banned.
- The criminal code (2000) prohibits fertilization of a human ovum with intent other than procreation and prohibits genetic manipulation for the purpose of reproductive cloning. The code does allow the fertilization of human ova for research and diagnostic purposes, if there is a therapeutic goal.

Ecuador

- Embryonic stem cell research, therapeutic cloning, and reproductive cloning are banned.
- Research on human embryos (and therefore cloning) is prohibited (June 1998).

Peru

- Embryonic stem cell research is not specifically prohibited, but therapeutic and reproductive cloning are banned.
- General Health Law states that fertilization of a human ovum with intent other than procreation is prohibited, as well as is human cloning (1997).

Uruguay

- Reproductive cloning is explicitly prohibited.

Europe

Austria

- Embryonic stem cell research, therapeutic cloning, and reproductive cloning are banned.

Belgium

- Therapeutic cloning as well as embryonic stem cell research is legal.
- Reproductive cloning is prohibited (2003).

Czech Republic

- Reproductive cloning is banned.
- Embryonic stem cell research is permitted.

Denmark

- Therapeutic cloning is permitted (2003) while embryonic stem cell research is not specifically prohibited.
- Reproductive cloning is explicitly banned.

Estonia

- All forms of human cloning (reproductive and therapeutic) are specifically banned.
- Embryonic stem cell research is allowed.

Finland

- Reproductive cloning is specifically prohibited (1999).
- Therapeutic cloning and embryonic stem cell research is permitted.
- An embryo is defined as a fusion of gametes, so therapeutic cloning is permitted, but reproductive cloning is prohibited (Medical Research Act of 1999).

France

- All forms of cloning (reproductive and therapeutic) is prohibited (Bioethics Law, 2004).
- Embryonic stem cell research is permitted, law will be reviewed in 2009.

Georgia

- Reproductive cloning (human cloning) and therapeutic cloning are banned (1997).
- Embryonic stem cell research is not specifically prohibited.

Germany

- Reproductive cloning and therapeutic cloning are explicitly banned.
- Embryonic stem cell research is restricted to embryos imported before May 2007.

Greece

- All cloning (reproductive and therapeutic) is prohibited (2002).
- Embryonic stem cell research is permitted.

Hungary

- Reproductive cloning is explicitly prohibited (Law No. 154).
- Embryonic stem cell research and therapeutic cloning are not addressed and therefore permitted.

Iceland

- Reproductive cloning and therapeutic cloning is banned (Act on Artificial Fertilisation, 1996).
- Embryonic stem cell research is permitted with restrictions.

Ireland

- Embryonic stem cell research, reproductive cloning, and therapeutic cloning are banned.
- Human cloning is prohibited because the "right to life of an unborn child is equal to that of the mother," as stated in the Constitution of Ireland.

Italy

- Reproductive cloning and therapeutic cloning are explicitly prohibited.
- Embryonic stem cell research is allowed with heavy restrictions.

Latvia

- Reproductive cloning and therapeutic cloning are prohibited (Law on Sexual and Reproductive Health, 2002).
- Embryonic stem cell research is permitted.

Lithuania

- Embryonic stem cell research, therapeutic cloning, and reproductive cloning are prohibited.
- Human embryos may be subjects only of clinical observations (noninvasive investigations).

The Netherlands

- All forms of cloning (reproductive and therapeutic) are prohibited.
- Embryonic stem cell research is permitted with restrictions.

Norway

- Embryonic stem cell research, reproductive cloning, and therapeutic cloning are all banned.

Poland

- Human reproductive cloning and embryonic research are specifically prohibited.
- Human embryos may not be used for nontherapeutic research.

Portugal

- Reproductive cloning and therapeutic cloning is banned (National Council of Ethics for the Life Sciences, 1997).
- Embryonic stem cell research is permitted.

Russian Federation

- Reproductive cloning is prohibited.

Slovakia

- Embryonic stem cell research, reproductive cloning, and therapeutic cloning are prohibited.

Slovenia

- Embryonic stem cell research is not specifically prohibited, but therapeutic and reproductive cloning are (Law on Medically Assisted Reproduction, 2001/ Penal Code, 2002).

Spain

- Embryonic stem cell research and therapeutic cloning are legalized.
- Reproductive cloning is banned.

Sweden

- Reproductive cloning is prohibited.
- Embryonic stem cell research and therapeutic cloning are legalized.

Switzerland

- Prohibits reproductive cloning and therapeutic cloning.
- Embryonic stem cell research is allowed with restrictions.

Turkey

- Prohibits reproductive cloning (1996).
- Embryonic stem cell research and therapeutic cloning (SCNT) are not specifically prohibited.

Ukraine

- Reproductive cloning is prohibited (2004).

United Kingdom

- Allows for embryonic stem cell research as well as legalizing therapeutic cloning.
- Reproductive cloning is banned.
- Therapeutic cloning is regulated by the Human Fertilization and Embryology Authority (HFEA).

Asia & Oceania

Australia

- Reproductive cloning is prohibited.
- Therapeutic cloning is legalized and embryonic stem cell research is permitted.
- Researchers must apply for a license to experiment with embryos.

China

- Embryonic stem cell research and therapeutic cloning are permitted, but reproductive cloning is banned.

- "Guidelines for Research on Human Embryonic Stem Cells" released in 2004 by China's Ministry of Science and Technology, and Ministry of Health.

Hong Kong (Special Administrative Region of China)

- Prohibits all forms of cloning (reproductive and therapeutic).

India

- Embryonic stem cell research and therapeutic cloning are permitted, but reproductive cloning is banned.
- The Indian Council of Medical Research released the Consultative Document on Ethical Guidelines for Biomedical Research on Human Subjects (2000), which cover the guidelines.

Japan

- Embryonic stem cell research and therapeutic cloning are permitted, but reproductive cloning is banned.

New Zealand

- Reproductive cloning is explicitly prohibited (Human Assisted Reproductive Technology Bill, 2004).

Singapore

- Reproductive cloning is specifically banned.
- Therapeutic cloning and embryonic stem cell research is permitted with strict guidelines.

South Korea (Republic of Korea)

- Embryonic stem cell research and therapeutic cloning are permitted, but reproductive cloning is banned.
- The government approved research on somatic cell nuclear transfer based on guidelines of National Ethics Committees.

Taiwan

- Embryonic stem cell research is allowed on excess stocks of embryos produced naturally for artificial insemination.
- Reproductive and therapeutic cloning are banned, as is the creation of embryos for research purposes.

Thailand

- Reproductive cloning is explicitly prohibited.

Vietnam

- Embryonic stem cell research is not specifically prohibited, but therapeutic and reproductive cloning are.
- Human cloning and surrogacy banned as of May 2003.

Middle East & Africa

Egypt

- Reproductive cloning is prohibited by an "opinion" issued by the Egyptian government which reflects the views of the Islamic Research Academy.

Iran

- Embryonic stem cell research is permitted.
- Iranian Islamic scholars interpret the Koran to indicate that life does not begin until the 120th day after conception.

Israel

- Prohibits reproductive cloning and germ line genetic engineering.
- Allow for therapeutic cloning (SCNT) as well as embryonic stem cell research.

Tunisia

- National Medical Ethics Committee "Opinion No.3" (1997) prohibits all technology which is related to human cloning including reproductive and therapeutic cloning (SCNT).
- Law 01-93 (2001) Restricts embryonic stem cell research by banning the obtainment of an embryo for study, research, or experimentation.

Saudi Arabia

- Religious leaders enacted a "fatwa" which allows for use of embryos for therapeutic cloning (SCNT) as well as embryonic stem cell research.

South Africa

- Embryonic stem cell research is permitted.
- All forms of cloning (reproductive and therapeutic) are banned.

Stem Cell Research
Glossary

adult stem cell: An unspecialized or undifferentiated cell found among specialized cells in a tissue or organ, which can renew itself and differentiate into a specialized cell.

autoimmune disease: A disease where one's own body starts attacking itself and destroying its own cells.

ß-cell: A cell in the pancreas which is responsible for the production and regulation of insulin.

blastocyst: A preimplanted embryo of 30 to 150 cells that is five-to-six days old.

cell-based therapies: Treatment in which stem cells are induced to differentiate into the specific cell type required to repair damaged or depleted adult cell populations or tissues.

cell line: A collection of cells grown in a laboratory and representing generations of a single cell or set of cells.

characterizing stem cells: Determining how a cell grows, where the cell came from, how it was derived, and if there are any chromosomal abnormalities.

cloning: In biology, it is the act of producing an exact copy of a sequence of DNA, cell, tissue, or organism.

Department of Health and Human Services (DHHS): The United States government's principal agency for protecting the health of all Americans. It provides essential human services, especially for those who are least able to help themselves.

deriving: The creation of a cell line from one original cell or set of cells.

differentiation: The process of unspecialized cells transforming into specialized cells.

embryo: In humans, the developing organism from the time of fertilization until the end of the eighth week, when it becomes known as a fetus.

embryonic stem cell (ESC): An unspecialized or undifferentiated cell, found in the inner cell mass of a blastocyst, that can renew itself and differentiate into a specialized cell.

endoderm: The internal layer of cells of an embryo that eventually gives rise to the digestive tract, lungs, and associated structures.

fetus: A developing human from the eighth week after fertilization to birth.

gamete: A mature sexual reproductive cell (sperm or egg) having a single set of unpaired chromosomes.

hematopoietic stem cell: An adult stem cell from which all white and red blood cells evolve.

induced Pluripotent stem cells (iPS cells): Normal cells which have been deprogrammed through forced gene expression back to the pluripotent stage (similar to ESC).

inner cell mass: A small group of about 30 cells in a blastocyst which will give rise to the hundreds of highly specialized cells needed to make up an adult organism; embryonic stem cells are derived from this group.

insulin: A hormone in the body that balances blood sugar levels.

in vitro: From the Latin for "in glass"; it means observing something in a laboratory dish, test tube, or artificial environment.

in vitro fertilization (IVF): An assisted reproduction technique in which fertilization is accomplished outside the body.

in vivo: In the living subject; the natural environment.

juvenile diabetes: Also known as type 1 diabetes, it is an autoimmune disease where the ß-cells in the pancreas are destroyed and therefore the individual loses some or all of his/her ability to regulate and produce insulin. If left untreated, it can have severe side effects such as kidney failure, blindness, stroke, and even death.

National Bioethics Advisory Council (NBAC): A committee of experts formed in 1995 during the Clinton administration to provide advice and make recommendations to appropriate government entities related to bioethical issues. Its charter expired in October 2001.

National Institutes of Health (NIH): An agency of the Department of Health and Human Services, its mission is the pursuit of knowledge about nature and behavior of living systems. It provides leadership and direction to programs designed to improve health by conducting and supporting research in the following areas: in the causes, diagnosis, prevention, and cure of human diseases; in the processes of human growth and development; in the biological effects of environmental contaminants; in the understanding of mental, addictive, and physical disorders; in directing programs for the collection, dissemination, and exchange of information in medicine and health, including the development and support of medical libraries and the training of medical librarians and other health information specialists.

nucleus: A structure within a living cell that contains the cell's DNA and controls its metabolism, growth, and reproduction.

oocyte: A female cell that develops into an ovum (egg) after meiosis; an egg before maturation.

ovum: The female reproductive cell or egg (plural is ova).

pluripotent: The ability of a single cell to develop into many different cell types of the body.

President's Council on Bioethics (PCB): A committee of experts that was formed in 2001 during the Bush administration (after the NBAC was disbanded) to provide the President with advice on bioethical issues that may emerge as a result of biomedical science and technology.

proliferation: Expansion of a population of cells by the continuous division of single cells into two identical cells.

quiescent: A cell that does not divide or replicate.

reproductive cloning: The process by which an egg undergoes somatic cell nuclear transfer and the resulting cell is allowed to grow to an infant that is an exact copy of the donor.

signals: Internal and external factors that control the changes in cell structure and function.

smooth muscle: Also known as "involuntary muscle," these muscles perform automatic tasks such as peristalsis and blood vessel constriction. Named smooth muscle because of smooth, rather than striated, appearance under a microscope.

somatic cell: Any cell of a plant or animal other than a germ (sperm or egg) cell.

somatic cell nuclear transfer (SCNT): The process by which the genetic material (nucleus) of an egg is removed and replaced with the genetic material of a normal cell.

stem cell: An unspecialized cell that can replicate itself for indefinite periods through cell division and under certain conditions become a specialized cell.

therapeutic cloning: When embryonic stem cells created by somatic cell nuclear transfer are studied in vitro and used for cell-based therapies, but never are implanted in a female or grown past 14 days.

undifferentiated cell: A primitive cell that does not have any tissue-specific structures that allows it to perform specialized functions. It has not changed to become a specialized cell.

zygote: The cell (and the organism that develops from the cell) resulting from the union of an ovum (egg) and sperm (also referred to as a fertilized ovum or fertilized egg).

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