**Anatomy of a Stem Cell**

Stem cells are the fundamental source of all the body's tissues, the template from which bodily cells are derived. As cells die off or are damaged, the hundreds of thousands of stem cells in the human body give rise - constantly - to new tissue. Injuries as simple as the scalding of the mouth with a hot beverage and as grave as the compromising of the immune system during chemotherapy require the activity of stem cells to repair cellular damage.

While all stem cells share certain unique attributes - the ability to self-renew and the ability to differentiate into various other types of cells - they are often divided into two primary types, embryonic and adult stem cells. Scientists are most interested in embryonic stem cells because these cells are capable of generating all the tissues in the body; they are unlimited in their potential. Embryonic stem cells are normally found in embryos at the blastocyst stage of development, a period just days after conception when the embryo is a hollow ball of no more than a few hundred cells that have not yet begun to differentiate into specific organs.

As human development proceeds both in the womb and after birth, the body's stem cells become increasingly specialized. These more restricted cells are known as adult stem cells, and they give rise only to limited types of tissue. For instance, blood stem cells create red and white blood cells, among others, while neuronal stem cells give rise to cells of the brain and nervous system. Adult stem cells capable of forming new tissue have now been identified for most organs, although notably, not for the pancreas.

Adult stem cells are already used widely as a complement to chemotherapy: Oncologists inject stem cells into the bloodstream, and the cells migrate to areas of the body where they are needed to regenerate the immune system. The success of this model hints at tremendous opportunities for stem cells to be used to rebuild other tissues.

Researchers would like to use stem cells much more aggressively, harnessing their therapeutic power to generate virtually all types of damaged tissue. In addition to coaxing transplanted stem cells to replace bodily cells that have been harmed, scientists would also like to be able to enhance the ability of existing stem cells within the body to initiate repair.

To be maximally useful, stem cell science requires using a process in which the nucleus of an egg, which contains its genetic material, is removed and replaced by the genetic material from an adult cell. This egg, with its new nucleus, then grows into a cluster of cells from which investigators can derive stem cells matching the genetic identity of the patient who donated the implanted cells, and which are therefore unlikely to be rejected by the patient's immune system. This technique, called somatic cell nuclear transfer, or therapeutic cloning, is distinct from the reproductive cloning used to create animals that are genetically identical to the parent.

**Benefits of Stem Cell Research**

There are many ways in which human stem cells can be used in research and the clinic. Studies of human embryonic stem cells will yield information about the complex events that occur during human development. A primary goal of this work is to identify how undifferentiated stem cells become the differentiated cells that form the tissues and organs. Scientists know that turning genes on and off is central to this process. Some of the most serious medical conditions, such as cancer and birth defects, are due to abnormal cell division and differentiation. A more complete understanding of the genetic and molecular controls of these processes may yield information about how such diseases arise and suggest new strategies for therapy. Predictably controlling cell proliferation and differentiation requires additional basic research on the molecular and genetic signals that regulate cell division and specialization. While recent developments with iPS cells suggest some of the specific factors that may be involved, techniques must be devised to introduce these factors safely into the cells and control the processes that are induced by these factors.

Human stem cells are currently being used to test new drugs. New medications are tested for safety on differentiated cells generated from human pluripotent cell lines. Other kinds of cell lines have a long history of being used in this way. Cancer cell lines, for example, are used to screen potential anti-tumor drugs. The availability of pluripotent stem cells would allow drug testing in a wider range of cell types. However, to screen drugs effectively, the conditions must be identical when comparing different drugs. Therefore, scientists must be able to precisely control the differentiation of stem cells into the specific cell type on which drugs will be tested. For some cell types and tissues, current knowledge of the signals controlling differentiation falls short of being able to mimic these conditions precisely to generate pure populations of differentiated cells for each drug being tested.

Perhaps the most important potential application of human stem cells is the generation of cells and tissues that could be used for cell-based therapies. Today, donated organs and tissues are often used to replace ailing or destroyed tissue, but the need for transplantable tissues and organs far outweighs the available supply. Stem cells, directed to differentiate into specific cell types, offer the possibility of a renewable source of replacement cells and tissues to treat diseases including macular degeneration, spinal cord injury, stroke, burns, heart disease, diabetes, osteoarthritis, and rheumatoid arthritis.

For example, it may become possible to generate healthy heart muscle cells in the laboratory and then transplant those cells into patients with chronic heart disease. Preliminary research in mice and other animals indicates that bone marrow stromal cells, transplanted into a damaged heart, can have beneficial effects. Whether these cells can generate heart muscle cells or stimulate the growth of new blood vessels that repopulate the heart tissue, or help via some other mechanism is actively under investigation. For example, injected cells may accomplish repair by secreting growth factors, rather than actually incorporating into the heart. Promising results from animal studies have served as the basis for a small number of exploratory studies in humans (for discussion, see call-out box, "Can Stem Cells Mend a Broken Heart?"). Other recent studies in cell culture systems indicate that it may be possible to direct the differentiation of embryonic stem cells or adult bone marrow cells into heart muscle cells (Figure 3).

In people who suffer from type 1 diabetes, the cells of the pancreas that normally produce insulin are destroyed by the patient's own immune system. New studies indicate that it may be possible to direct the differentiation of human embryonic stem cells in cell culture to form insulin-producing cells that eventually could be used in transplantation therapy for persons with diabetes.

To realize the promise of novel cell-based therapies for such pervasive and debilitating diseases, scientists must be able to manipulate stem cells so that they possess the necessary characteristics for successful differentiation, transplantation, and engraftment. The following is a list of steps in successful cell-based treatments that scientists will have to learn to control to bring such treatments to the clinic. To be useful for transplant purposes, stem cells must be reproducibly made to:

 Proliferate extensively and generate sufficient quantities of cells for making tissue.

 Differentiate into the desired cell type(s).

 Survive in the recipient after transplant.

 Integrate into the surrounding tissue after transplant.

 Function appropriately for the duration of the recipient's life.

 Avoid harming the recipient in any way.

Also, to avoid the problem of immune rejection, scientists are experimenting with different research strategies to generate tissues that will not be rejected.

**Ten Problems with Embryonic Stem Cell Research**

Embryonic stem cells are the basic building blocks for some 260 types of cells in the body and can become anything: heart, muscle, brain, skin, blood. Researchers hope that by guiding stem cells in the laboratory into specific cell types, they can be used to treat diabetes, Parkinson's disease, heart disease, or other disorders. The primary clinical source is the aborted fetus and unused embryos currently housed in frozen storage at IVF facilities. A developed stem cell line comes from a single embryo, becoming a colony of cells that reproduces indefinitely. Consider now the following ten problems with Embryonic Stem Cell Research (ESCR).

**1. The issue of who or what**

As the nation sits embroiled over the battle of where to draw the line on ESCR, the real issue that truly divides us is whether embryonic stems represent a who or a what. In other words, are we talking about people or property?

Since Roe v. Wade we have not been willing or able as a nation to address the issue. As a result, those who oppose ESCR and those who support it will never reach an acceptable point of compromise. Still, in the midst of the flurry of all this biotechnology and all the problems it presents, there is some very good news that has been overlooked by almost everyone. Ready? Cloning proves scientifically that **life begins at conception**—a position to which the author and most Christians philosophically already adhere.

Additionally, the insights provided by cloning technology destroy the scientific and legal basis of distinguishing a preembryo from an embryo, the popular distinction made at 14 days after conception. This is significant because this distinction determines the handling and treatment of human life less than 14 days old, which is so basic to all ESCR.

In short, our understanding of embryonic development as provided by cloning technology could force not only those who participate in ESCR specifically, but also those who participate in in-vitro fertilization (IVF) procedures generally, to recognize there is no real preembryo—embryo distinction and that all human life begins at conception. Therefore, as a nation, we should rightly adjust the moral and legal treatment and status of all embryos to people not property from the point of conception.

**2. The deliberate misuse of terminology in defining stem cells**

Proponents of ESCR often use the term pluripotent. This word intends to imply that the ESC cannot make or reform the outer layer of the embryo called the trophoblast. The trophoblast is required for implantation of the embryo into the uterus. This is a distinction used by proponents of ESCR to imply a fully formed **implantable embryo** cannot and does not reform after the original embryo is sacrificed. This is significant because to isolate the stem cells, scientists peel away the trophoblast or skin of the embryo much like the peel of an orange. They then discharge the contents of the embryo into a petri dish.

At this stage of development, the stem cells that comprise almost the entire **inner body** of the early embryo look and function very similar to one another. Once put into the petri dish, the un-programmed cells can be manipulated to multiply and divide endlessly into specific cell types. The question regarding use of the term pluripotent is whether stem cells emptied into the petri dish can reform the trophoblast creating an **implantable embryo** of the originally sacrificed embryo?

The uncomfortable truth is, James Thomson, who led the effort that first isolated and grew embryonic stem cells in the laboratory says the trophoblast can reform under certain circumstances. That means even after months of continuous proliferation of the cells, implantable cloned human beings of the original embryo might be forming as the stem cells are grown in petri dishes. Therefore, use of the term pluripotent is scientifically inaccurate and deliberately misleading.

**3. ESCR is related to human cloning**

Understanding how ESCR and human cloning relate requires delineation between the two forms of human cloning: reproductive and therapeutic.

Reproductive cloning creates a later born twin from a single cell of another person by transplanting the DNA of the adult cell into a human egg whose nucleus has been removed. This process is somatic cell nuclear transfer. In this procedure, the resulting embryo is implanted in a woman and carried to birth. Proponents say that reproductive cloning is a logical extension of infertility treatments, hence the intimate link to IVF procedures.

By contrast, therapeutic cloning occurs when an adult undergoes a cloning procedure to duplicate his own cells in order to stave off personal disease, illness or the effects from sudden and serious injury. This procedure also begins by creating a clone of the adult through somatic cell transfer. In therapeutic cloning however, the embryos are allowed to live up to 14 days, at which time their trophoblasts are removed, as in standard ESCR, to harvest the highly prized stem cells for the donor's treatment.

In summary, therapeutic cloning begins with the same procedure as reproductive cloning. The goal of reproductive cloning is to produce a baby. The goal of therapeutic cloning is to produce embryonic stem cells for research and or treatment.

Additionally, whenever embryonic stem cell research results in the spontaneous reformation of the trophoblast around other stem cells, a fully implantable cloned life of the originally sacrificed embryo is created, however temporarily.

**4. The current status of ESCR in the U.S. is unsettled at best**

President Bush announced on August 9, 2001, that federal funds would not be used for ESCR that result in the future destruction of embryos. They can, however, be used to conduct research on the 64 stem cell lines that currently exist because "the life-and-death decision has already been made." However, scientists who work with some of these cells say many of the 64 lines are not yet developed and some may never pan out. Some researchers are uncertain about the quality of the cells and wonder if the limited number is enough. Proponents of this research are now focused on gaining more ground by passing legislation in Congress.

**5. There is law that could apply to ESCR**

Originally attached to the 1995 Health and Human Services (HHS) appropriations bill, the "Dickey Amendment" has prohibited federal funding of "any research in which a human embryo or embryos are destroyed, discarded or knowingly subjected to risk of injury or death."Unfortunately, there are no laws to protect preembryos (embryos under 14 days old) or that prohibit private individuals, research firms, or pharmaceutical companies from forming, manipulating, or destroying stem cells, human clones, or embryos.

**6. Polls show that the American people do not approve using public money to destroy human embryos in medical research**

**7. ESCR puts us on the road to growing humans for body parts**

The un-programmed cells of an early embryo are derailed from their natural course of development and coaxed through chemical manipulation to become very specific tissue types that will be used to treat the unhealthy or diseased tissue of those already born. Opponents of funding ESCR have argued vehemently against this stark utilitarian treatment of human life, unfortunately with little effect.

Regarding the justification that the embryos "left over" in IVF clinics (reportedly >300,000 in the US alone) will simply be discarded anyway, reflects a chilling absence of moral conscience. We do not consider it appropriate to take organs from dying patients or prisoners on death row **before** they have died in order to increase someone else's chances for healing or cure. Neither, then, should we consider any embryos "spare" so that we may destroy them for their stem cells.

How far down this road have we already come? Consider the story of Adam and Molly Nash. Molly was diagnosed with Fanconi anemiaa hereditary and always fatal disease. Doctors determined that the best hope for Molly was a cell transplant from a relative whose cells matched Molly's, but without anemia. So Molly's parents produced fifteen embryos by IVF, only one of which had the right genetic material. It was implanted in Mrs. Nash who gave birth to Adam. Adam's stem cells were taken from his umbilical cord and implanted in his sister. Despite all the success of the treatment and the medical justification, the fact remains that Adam was conceived, not just to be a son, but a medical treatment. Adam was a means valuable only insofar as he carried the right genetic material. If he hadn't, he would have been rejected like the other fourteen discarded embryos. The undeniable conclusion is that we are growing humans for body parts.

**8. Contemporary moral issues often follow the flow of money**

Stem cell research and human cloning are about transforming the mystery and majesty of life into a mere malleable and marketable commodity. In the short term, this is big business and offers great fame and fortune to the pioneers and biotech companies who master their secrets and harness the power of life through ESCR.

**9. ESCR currently has major disadvantages**

The promises of ESCR are right now nothing more than hoped for possibilities. Successful clinical trials for people are years away at best. Why? The reality is that the scientific evidence so far does not support public statements.

First, one minor complication is that use of human embryonic stem cells requires lifelong use of drugs to prevent rejection of the tissue. Second, another more serious disadvantage is that using embryonic stem cells can produce tumors from rapid growth when injected into adult patients. A third disadvantage reported in the March 8, 2001, New England Journal of Medicine was of tragic side effects from an experiment involving the insertion of fetal brain cells into the brains of Parkinson's disease patients. Results included uncontrollable movements: writhing, twisting, head jerking, arm-flailing, and constant chewing. Fourth, a recent report in the Journal Science reported that mice cloned from ESC were genetically defective. If human ESC are also genetically unstable, that could materially compromise efforts to transform cells extracted from embryos into successful medical therapies. Finally, the research may be hampered because many of the existing stem cell lines were grown with the necessary help of mouse cells. If any of this research is to turn into treatments, it will need approval from the FDA, which requires special safeguards to prevent transmission of animal diseases to people. It is unclear how many of these cell lines were developed with the safeguards in place. This leads to a host of problems related to transgenic issues.

**10. The Success and Promise of Adult Stem Cell Research**

In all fairness, adult stem cells have restricted differentiation potential and do not proliferate as well as ESC. On the other hand, while ESCR yields, at best, meager results, and has only far distant possibilities of successful clinical applications, current clinical applications of adult stem cells are abundant! They include treatments for the following: corneal restoration, brain tumors, breast cancer, ovarian cancer, liver disease, leukemia, lupus, arthritis, and heart disease. Thousands of patients are treated and cured using adult stem cells. Alternative sources for adult stem cells include: placenta, cord blood, bone marrow organ donors, and possibly fat cells.

For these ten reasons my conclusion is that more dollars should be invested in adult stem cell research and the macabre research associated with ESCR should be abandoned entirely.