CRG STEM CELL PRIMER
A Briefing Paper for the EGA Institute

STEM CELLS DEFINED

Next time you look at yourself in the mirror, be amazed. You are made up of trillions of cells! These trillions of cells make up over 200 known cell types found in the different tissues of your body. Each type of mature cell is specialized to perform a specific function, such as photoreceptor cells in your eye that allow you to see the words on this page. Photoreceptor cells, and all other cells in the body, are derived from so-called *"stem cells."* These are the cells from which specialized cells stem. They are the source of all the different types of cells that make up our bodies, such as muscle cells, bone cells, skin cells, brain cells, and more.

Although scientists dispute the exact qualities that define a stem cell, most people agree that stem cells, like most other cells, have the ability to divide and produce more cells like the original cell. This process is often called *self-renewal.* As they divide, stem cells can also produce mature cells specialized for specific and fixed roles in the body. As far as we know, populations of stem cells reproduce throughout our lives. Our bodies are supplied with new cells by stem cells existing in many of our tissues. In adults, such stem cells serve to replace dying cells. For instance, there are stem cells underneath our skin that replace the cells that we lose through normal wear and tear.

Even though stem cells lie among tissues, such as muscle, bone, skin, and brain, with specialized functions, they do not exhibit the specialized appearance and function of the cells they give rise to. They yield cells that are further specialized by responding to signals from other cells. Often, stem cells in a specific organ can become any of the many different types of cells present in that organ.

Some stem cells produce precursor or *progenitor cells*, and these add an additional step in the maturation pathway. Precursor cells are similar to stem cells in that they have the ability to produce at least one functionally specialized type of cell, but unlike stem cells, they are unable to self-renew, or produce more of themselves.

If a stem cell has the potential to produce more stem cells and only one kind of specialized cell it is known as *unipotent.*

Stem cells are known as *pluripotent* if in addition to reproducing themselves, they can produce many different types of specialized cells. Examples include *hematopoietic stem cells* (HSCs are found in the bone marrow of adults), which can produce more HSCs, as well as red blood cells, white blood cells, and cells of the immune system; and the now famous *embryonic stem cells (ESCs*), which can produce HSCs as well as all the different known types of cells that make up our bodies. However, ESCs cannot produce all the cells necessary for survival of an embryo, as they cannot give rise to the placental tissue.

Totipotent cells can produce any type of cell necessary for the survival of the embryo. The only truly totipotent cells are the result of the fusion of egg and sperm, a zygote, and the cells resulting from the initial divisions of the zygote, the *blastomeres.* However, neither the zygote nor the blastomeres are considered to be stem cells, because the number of cell divisions they undergo before differentiating into either ESCs or placental tissue is strictly limited.

USES OF STEM CELLS

Scientists are currently performing research to learn whether, in addition to being important in replenishing many types of cells

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in our bodies, stem cells will be useful to treat certain diseases. Stem cells may be used to study tissue development and to test new pharmaceuticals.

Researchers hope that by culturing pluripotent stem cells in the presence of different growth factors and attempting to control the expression of specific genes, they may direct the development of the stem cell to yield specific types of cells that could benefit people with specific diseases. However, if stem cells are ever going to be viable as treatments, their differentiation and proliferation must be controlled. Otherwise, people could develop tumors, or the wrong types of cells, such as bone cells growing in the heart. It is easy to get excited about stem cells, considering the media hype, but at present, treatments for human diseases using most stem cells are only a possibility. With the exception of one type of adult stem cell found in the bone marrow, no stem cells are currently used for the treatment of human diseases. Most stem cell research is in its infancy, in animal testing stages.

SOURCES OF HUMAN STEM CELLS

Adults: Adult stem cells (ASCs) have been found in many tissues in our bodies such as bone marrow, blood, brain, muscle, skin, liver, pancreas, intestinal lining, eyes, and tooth pulp.

Umbilical cord blood of newborns: Stem cells found here are also considered ASCs, although they have a greater ability to proliferate than stem cells from adult humans.

Placental tissue: source of ASCs also commonly called "afterbirth."

Embryos: Cells from the inner cell mass (ICM) of an embryo can give rise to embryonic stem cells (ESCs).

Fetal tissue: "Embryonic" germ cells (EGCs) have been derived for research from cells found in the gonadal region of an aborted fetus. The cells from which EGCs are derived would produce precursors of eggs or sperm if the fetus continued to develop. In reports about an experiment that resulted in partial restoration of neural function in mice, these cells have often been misleadingly called another type of embryonic stem cell. While embryonic stem cells can be produced directly from cells derived in vitro (outside the body) from eggs and sperm, embryonic germ cells cannot. The reason that EGCs cannot be derived from embryos is because they are produced later during fetal development. ESCs and EGCs also have different properties, and are not equivalent sources of stem cells.

EMBRYONIC STEM CELLS

Embryonic stem cells have been the recent focus of the popular media. As far as we know, these stem cells develop into the greatest number of different types of cells and they proliferate rapidly. Due to their special properties, some scientists feel that research on ESCs should be federally funded, despite ethical concerns that have restricted funding for embryo research. On August 9th, 2001, President Bush announced his decision to allow federal funding for research on ESC lines that had been derived from embryos left over from in vitro fertilization prior to his announcement. He prohibited federal funding for research on embryos produced solely for research purposes, and on cloned embryos. President Bush's decision does not affect privately funded ESC research.

Researchers collect embryonic stem cells from the inner cell mass of a blastocyst. The blastocyst is the name for the structure formed at the stage of development just before the embryo would normally implant in the lining of a woman's uterus. At this stage, the cells of the embryo begin to separate into two domains, the *trophoblast* and the *inner cell mass (ICM).* The trophoblast forms a hollow ball that will later give rise to the placental tissue. The ICM is a cluster of cells attached to the inside of the hollow sphere, and it will give rise to the tissues of the developing fetus.

Embryonic stem cells are derived from inner cell mass (ICM) cells removed from the embryo at 5 days post-fertilization. The procedure destroys the embryo. Cells from the ICM are placed into a culture medium. Most of them divide a few times and then die, but a few continue to proliferate. These are the embryonic stem cells. Since they can produce further identical embryonic stem cells, they are known as ESC "lines."

ESCs can be generated in three ways. To date, most of the research has been conducted with embryos that were produced during in vitro fertilization but were not implanted in a woman's uterus. However, in July 2001, scientists at the Jones Institute for Reproductive Medicine produced human embryos solely for research purposes. They did so by paying women for their eggs and men for their sperm and producing an embryo in vitro. A third possibility is to produce clonal embryos by using a technique known as somatic cell nuclear transfer.

For the somatic cell nuclear transfer procedure, the nucleus is removed from a som`atic cell, such as a skin cell, by means of small needle. The nucleus is then inserted into an egg cell whose own nucleus has been removed. Some synthetic cells produced this way begin to divide as though the egg had been fertilized, and produce ESCs. Researchers are hoping that this procedure will allow cells produced by these genetically modified ESCs to be more readily accepted by the donor of the original skin cell. However, if a bill recently passed in the House of Representatives becomes law, this procedure would be outlawed.

CONCERNS AND CAUTIONS

Many people fear that experimentation on human embryos, coupled with our knowledge of the human genome, will lead us down a dangerous path to modifying the inborn characteristics of children, and thus create a new eugenics movement. The more we learn about early human development, the more tempted we may be to attempt to change characteristics. Testing IVF embryos for certain traits, such as sex, is already taking place. Scientists can then implant only the embryos that have the desired trait into a woman's uterus.

The majority of ESC lines have been derived from embryos left over from in vitro fertilization, but women have also be paid to provide their eggs so that biotechnology companies can produce embryos for research. In either case, women are given a series of drugs to increase the number of eggs that develop. There is some evidence of a possible increased risk of breast or ovarian cancer, though the exact risk is unknown as studies are contradictory and incomplete. Health risks to women undergoing egg retrieval need to be taken into account in discussions about embryos.

It is important to keep in mind that research on embryonic stem cells may not lead to any useful treatments. In his August 9th television address, President Bush pointed out that fetal tissue once was hailed as a very promising potential source of treatments, but the research has yielded few positive results. In fact, a study cited in the New England Journal of Medicine reported that some patients with Parkinson's disease experienced terrible side effects in an experiment that involved the injection of fetal neurons into their brains. The study showed that we do not yet know how to control how fast these cells grow. Control of the proliferation and differentiation of any implanted cells must be accurate, since they cannot be removed once implanted. Attempts at cell transplantation could be very dangerous if researchers do not proceed with caution.

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