Stem Cell Introduction

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Abstract: The stem cell is the origin of an organism's life that has the potential to develop into many different types of cells in life bodies. In many tissues stem cells serve as a sort of internal repair system, dividing essentially without limit to replenish other cells as long as the person or animal is still alive. When a stem cell divides, each new cell has the potential either to remain a stem cell or become another type of cell with a more specialized function, such as a red blood cell or a brain cell.
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Normally, stem cells are classified as 4 types according to their plasticity: totipotent stem cell, pluripotent stem cell, multipotent stem cell, and the adult stem cell: (1) Totipotent Stem Cells. When a sperm cell and an egg cell fuse, it forms a fertilized egg called zygote. The fertilized zygote is a totipotent stem cell, which has the potential to give rise to any and all animal cells, such as blood, heart, brain, skin lung, liver cells, etc. It can even give rise to an entire functional organism. The first few cell divisions in embryonic development produce more totipotent cells. In human, after 4 days of embryonic cell division, the cells begin to specialize into pluripotent stem cells. (2) Pluripotent Stem Cells. Pluripotent stem cells are can give rise to all tissue types, but cannot give rise to an entire organism. In the human, on the 4th day of development, the embryo forms into two layers, an outer layer which will become the placenta, and an inner mass which will form the tissues of the developing human body. These inner cells, though they can form nearly any human tissue, cannot do so without the outer layer; so are not totipotent, but pluripotent. As these pluripotent stem cells continue to divide, they begin to specialize further. (3) Multipotent Stem Cells. Multipotent stem cells give rise to a limited range of cells within a tissue type. The offspring of the pluripotent cells become the progenitors of such cell lines the adult cells, such as nerve, blood, heart, lung, kidney and skin cells, etc. They can become one of several types of cells within a given organ. (4) Adult Stem Cells. The adult stem cell (also called somatic stem cell) is a multipotent stem cell in adult humans that is used to replace the cells that have died or lost function. It is an undifferentiated cell exits in differentiated tissue. It renews itself and can specialize to yield all cell types present in the tissue from which it originated. So far, adult stem cells have been identified for many different tissue types such as mesenchymal, neural, hematopoetic, endothelial, muscle, skin, gastrointestinal, and epidermal cells, etc.

Stem cells can develop into different cell types in the life body. Stem cell can divide into new stem cells or become another type of cell with a specialized function, such as a neural cell or a smooth muscle cell.

Stem cells have 2 characteristics: (1) Stem cells are unspecialized cells that can renew themselves by cell division. (2) Stem cells can be induced to specific cells.

Stem cells frequently divide in some organs (such as bone marrow) to repair and replace damaged cells. However, stem cells divide only under some special conditions in other cells, such as in the heart and pancreas.

Normally, there are 2 kinds of stem cells in the animals: (1) embryonic stem cells and (2) non-embryonic stem cells (also called somatic or adult stem cells).

The embryonic stem cell was discovered from early mouse embryos in 1981. Human empryonic stem cells are discovered in 1998. In 2006, people found that under specific condition some specialized stem cells can be reprogrammed. This new type of stem cell is called induced pluripotent stem cells (iPSCs). In the 3- to 5-day-old embryo (blastocyst), the inner cells of the blastocyst growth to the animal body that includes all specialized cells.

Stem cells can offer the possibility to treat diseases that are referred to as regenerative or reparative medicine.

Stem cells can be used in the drug development and life body growth when observing the growth of the stem cells.

Normally to say, stem cells have 3 properties: (1) Stem cells are capable of dividing and renewing themselves for a long period; (2) Stem cells are

unspecialized; (3) Stem cells can divide into specialized cell types.

The embryonic stem cells can proliferate for a year or more in the laboratory without differentiating, but most non-embryonic stem cells (somatic or adult stem cells) cannot. Certain factors in living organisms regulate the stem cell proliferation and self-renewal. Cell proliferation is regulated during the body growth and the cancer could happen if the regulation is out of control. The specific factors and conditions control the stem cells to remain the unspecialized condition or the specialized condition. It has been studied in the laboratory environment. Some specific signals in a mature organism cause a stem cell population to proliferate and remain unspecialized until the cells are needed. The study of these signals is important.

Normally to say, stem cells have no biological function in a living body but they can divide to the specialized cells for the biological functions.

It is called differentiation when the unspecialized stem cells give rise to specialized cells. Differentiation is a key process for the living body to live, and the specific signals (factors) are key important in this process. The signals play key roles to trigger the differentiation step in this process. The internal signals are controlled by a cell's genes. The external signals for cell differentiation include chemicals secreted by other cells or from outside of the body, physical contact with neighboring cells or outside of the body, and any related thing in the environment. The interaction of signals during differentiation causes the cell's DNA to acquire epigenetic marks that restrict DNA expression in the cell and can be passed on through cell division.

There are many questions in the signals to control the stem cell differentiation and these are important in the stem cell study.

Adult stem cells generate the cell types of the tissue where they are in. Normally, stem cells in blood generate blood cells. However, the current studies show that stem cells from one tissue may generate a completely different tissue cell.

The embryonic stem cells are derived from embryos that develop from fertilized egg.

Growing cells in the laboratory is called cell culture. Human embryonic stem cells (hESCs) are generated by transferring cells from a preimplantation-stage embryo into a plastic laboratory culture dish that contains the suitable culture medium. The cells divide on the dish surface. The inner surface of the culture dish can be coated with mouse embryonic skin cells as a feeder layer that has been treated to avoid dividing. The mouse cells in the culture dish bottom provide a sticky surface for the human embryonic cells to attach. And, the mouse feeder cells release nutrient materials into the culture medium for the target cells to use. The mouse feeder layer is a convenient way for the human target culture, but there are danger possibilities to introduce viruses or other harmful things to the cultured target cell. It could be improved by a medium for the target cells growth well without animal feeder layer.

The cultured embryonic stem cells can be subculturing and kept in the frozen condition (-70oC or lower).

Several tests to exam (characterize) whether the human embryonic stem cells exhibit the fundamental properties that make them as embryonic stem cells are available. (1) Growing and subculturing the stem cells for many months to make sure that the cells are capable of long-term growth and self-renewal. (2) Check the cells with a microscope to see that the cells look healthy and remain undifferentiated. (3) Confirm the presence of transcription factors that are typically produced by undifferentiated cells (such as transcription factors Nanog and Oct4, which maintain the stem cells in an undifferentiated state and capable of self-renewal). (4) Determine the presence of particular cell surface markers that are typically produced by undifferentiated cells. (5) Examine the chromosomes under a microscope to see whether the chromosomes are damaged or if the number of chromosomes has changed. (6) Determine whether the cells can be re-grown or subcultured after freezing, thawing and re-plating. (7) Test whether the human embryonic stem cells are pluripotent (differentiate cells in cell culture; manipulate cells to differentiate to form cells characteristic of the 3 germ layers; inject the cells into a mouse with a suppressed immune system to test for the formation of a benign tumor – teratoma, etc).

Stem cells can remain undifferentiated as longer as they are grown under certain suitable condition. If the cells begin to clump together to form embryoid bodies, they begin to differentiate spontaneously.

One method to treat disease is to different the culture human stem cells into specific cell types and transplant these cells to the damaged areas of the patient and the stem cell could replace the damaged cells.

The adult stem cell is an undifferentiated cell that exists among differentiated cells in a tissue or organ that can renew itself and can differentiate to some or all of the major specialized cell types of the tissue or organ. The primary roles of adult stem cells in a living organism are to maintain and repair the tissue where they are. The adult stem cell is also called somatic stem cell (somatic means the cells in the body, not in the sperm or eggs).

In the 1950s, it was discovered that the bone marrow contains at least two kinds of stem cells.

Hematopoietic stem cells form all the types of blood cells in the body. Bone marrow stromal stem cells (also called mesenchymal stem cells, or skeletal stem cells by some) were discovered a few years later. These non-hematopoietic stem cells make up a small proportion of the stromal cell in the bone marrow, and can generate bone, cartilage, fat, cells that support the formation of blood, and fibrous connective tissue. In the 1960s, it was found that two regions of the brain containing dividing cells ultimately become nerve cells. The adult brain contains stem cells that are able to generate the brain's 3 major cell types—astrocytes and oligodendrocytes and neurons.

Adult stem cells exist in many organs and tissues, such as blood vessels, bone marrow, brain, gut, heart, kidney, liver, lung, ovarian epithelium, peripheral blood, skeletal muscle, skin, stomach, teeth, testis, etc. They exist in a specific area of each tissue (stem cell niche). Some types of stem cells are pericytes (in the outermost layer of small blood vessels). Stem cells may remain quiescent (non-dividing) for a long time or whole life until they are activated by a normal need for more cells to maintain tissues, or by disease or tissue injury.

Normally, there are a very small number of stem cells in each tissue or organ. Once the stem cells are removed from the body, it is difficult to generate large quantity of the stem cells from them.

To identify adult stem cells: (1) Label the cells in a living tissue with molecular markers and then determine the specialized cell types they generate; (2) Remove the cells from a living animal, label them in cell culture, and transplant them back into another animal to determine whether the cells replace their tissue of origin.

Adult stem cells exist in all normal animals, and they can generate mature cells then that are needed in the living body.

Hematopoietic stem cells generate all the types of blood cells: red blood cells, B lymphocytes, T lymphocytes, natural killer cells, neutrophils, basophils, eosinophils, monocytes, and macrophages.

Mesenchymal stem cells exist in many tissues. Stem cells from bone marrow (bone marrow stromal stem cells, skeletal stem cells, etc) generate a variety of cell types: bone cells (osteoblasts and osteocytes), cartilage cells (chondrocytes), fat cells (adipocytes), and stromal cells that support blood formation.

Neural stem cells in the brain generate its 3 major cell types: nerve cells (neurons), astrocytes and oligodendrocytes.

Epithelial stem cells in the digestive tract growth to several kinds of cells: absorptive cells, goblet cells, Paneth cells and enteroendocrine cells, etc.

The epidermal stem cells can growth to keratinocytes that move to the skin surface to form a protective layer. The follicular stem cells can growth to hair follicle and epidermis.

For the stem cells growth, there is another phenomenon transdifferentiation. Abstract: Transdifferentiation is a non-stem cell transforming into a different type of cell, or a differentiated stem cell changing to another type of cells. Transdifferentiation is a type of metaplasia, which includes all cell fate switches, including the interconversion of stem cells. There are about 300 different types of cells, each specialized for a specific function. Most of our cells are matured cells, i.e. adult cells, rather than stem. The importance of the trandifferentiation is to transform the non-stem cell into a different type of cells. If we can transform the old cells to a young cell, we can keep the life living eternally and keep the life body in the younger stage forever. This is the really biological immortality – living eternal – we will not die (Yang and Ma, 2010). In the transdifferentiation, the adult stem cells can differentiate into different cell types, such as brain stem cells can differentiate into blood cells or blood-forming cells can differentiate into cardiac muscle cells. In the transdifferentiation, the adult cell can be reprogrammed into other kind of cells, which is possibly involved in the damage recover. The transdifferentiation could to offer a way for the life body to convert the life line process, i.e. to cause the life processing from older to younger. This possibly happens in a jellyfish Turritopsis nutricula. Turritopsis nutricula is a hydrozoan that can revert to the sexually immature (polyp stage) after becoming sexually mature. It is the only known metazoan capable of reverting completely to a sexually immature, colonial stage after having reached sexual maturity as a solitary stage. It does this through the cell development process of transdifferentiation. This cycle can repeat indefinitely that offers it biologically immortal. It is not clear if stem cells are involved in this immortality or not. Up to now, there is little academic report in the Turritopsis nutricula studies. To study the mechanism of the biological immortality of Turritopsis nutricula possibly supplies the way finding the biological immortality for human (Ma and Yang, 2010). The transdifferentiation is an important biological event, but still has debate.

The adult somatic cells could be reprogrammed to embryonic stem cells (induced pluripotent stem cells, iPSCs) through the introduction of embryonic genes. By this event, the donor cells can be from the recipient himself/herself that the gene background will be same for the donor and recipient.

Embryonic stem cells can become all cell types of the body as they are pluripotent. Normally, adult

stem cells can only differentiate into the cell types of their tissue of origin.

It is easier to culture embryonic stem cells than to culture adult stem cells. The tissues derived from embryonic and adult stem cells are differing in the likelihood of being rejected after transplantation.

A patient's own cells could be expanded in culture and differentiated into a specific cell type, and then reintroduced into the patient. Adult stem cells and tissues derived from the cells are less rejected after the transplantation as the donor and recipient can be the same person. The use of adult stem cells and tissues derived from the patient's own adult stem cells means that the cells are less likely to be rejected by the immune system. The immune rejection can be circumvented only by continuous administration of immunosuppressive drugs, and the drugs themselves could cause deleterious side effects.

Induced pluripotent stem cells (iPSCs) are adult cells that can be genetically reprogrammed to an embryonic stem cell. Mouse iPSCs were first discovered in 2006, and human iPSCs were first discovered in 2007. iPSCs can express stem cell markers and are capable of generating cells characteristic of all three germ layers. iPSCs are useful tools for drug development and medicine studies, such as transplantation medicine.

Viruses can be used to introduce the reprogramming factors into adult cells, However, there is a risk that the virus used to introduce the stem cell factors sometimes possibly causes cancers.

Controlling genes on and off is central to the biological process. The most serious medical conditions, such as cancer and birth defects, are due to abnormal cell division and differentiation.

Controlling cell proliferation and differentiation is key important in the natural biological process and also important in the medical studies. A lot of molecular and genetic signals that regulate cell division and specialization are involved in the controlling of cell proliferation and differentiation.

Human stem cells can be used to test new drugs directly. The safety for new medications can be tested on differentiated cells generated from human pluripotent cell lines. For example, cancer cell lines are used to find potential anti-tumor drugs. To control the differentiation of stem cell precisely is important in the drug development.

Currently, it may become possible to generate healthy heart muscle cells in the laboratory and then transplant these cells into patients with chronic heart disease. Cardiovascular disease (CVD) (including hypertension, coronary heart disease, stroke, and congestive heart failure, etc) is the number one cause of death in the United States since 1900. CVD keep the heart from getting oxygen, which damage the cardiac muscle. Restoring the damaged cells is a strategy way for this kind of diseases and stem cell treatment can do this. Cardiac stem cells (naturally reside within the heart), myoblasts (muscle stem cells), and bone marrow cells, mesenchymal cells, endothelial progenitor cells and umbilical cord blood cells are possible sources for regenerating damaged heart tissue.

To be useful for transplant purposes, stem cells must be reproducibly made to:

For the stem cell to be useful in the clinical application, the stem cells must be qualified for the following points: (1) Differentiate into the desired cells. (2) Survive in the recipient body after transplant. (3) Integrate into the surrounding tissue of the transplanted recipient after transplant. (4) Play appropriate function for a certain time in the recipient's body. (5) Not harmful for the recipient. (6) No significant problem of immune rejection

The stem cell is the origin of an organism's life that has the potential to develop into many different types of cells in life bodies. In many tissues stem cells serve as a sort of internal repair system, dividing essentially without limit to replenish other cells as long as the person or animal is still alive. When a stem cell divides, each new cell has the potential either to remain a stem cell or become another type of cell with a more specialized function, such as a red blood cell or a brain cell.

Stem cells have two important characteristics: (1) They are unspecialized cells capable of renewing themselves through cell division, sometimes after long periods of inactivity; (2) Under certain physiologic or experimental conditions, they can be induced to become differentiated adult cells with special functions. In some organs, such as the bone marrow, stem cells regularly divide to repair and replace worn out or damaged tissues. In other organs, however, such as the pancreas and the heart, stem cells only divide under special conditions. Stem cells can be used in the clinical medicine to treat patients with a variety of diseases (Daar, 2003). Serving as a repair system for the living body, the stem cells can divide without limit to replenish other cells as long as the living body is still alive. When a stem cell divides, each new cell has the potential to either remain a stem cell situation or become another type of cell with a more specialized function, such as a muscle cell, a red blood cell, a bone cell, a nerve cell, or a brain cell. Stem cell research is a typical and important topic of life science.

In 2003, it was found that foetal stem cells had the ability to multiply without limit and never grow old (Hawkes, 2003), which may make it possible to create foetal stem cells from adult cells. The gene Nanog is a regulator that controls the operation of

many other genes. It operates only in embryonic stem cells, which are pluripotent. Nanog's role is to maintain stem cells and to make them grow. Nanog is a master gene that may make stem cells immortal.

Embryonic stem cells can go on dividing forever. This means that a culture of stem cells can be kept alive for transplantation into patients where they will diversify into necessary cells. For this to be possible, it needs to know how it is that stem cells can either divide without limit, or choose instead to differentiate into specialized cells. Nanog appears to be the key. Nanog does not disappear in adult cells, but it lies dormant. This means that if a way could be found to reactivate it, adult cells could be persuaded to become embryonic cells again. The next step is to work out how Nanog is switched on and off. To achieve that it may be necessary to continue working on embryonic stem cells and watching the process as it happens.

Many diseases are caused by the death of cells vital to the proper functioning of the organs. Heart failure, for example, is often caused by damage to the muscles caused by a blood clot. Stem cells injected into the heart could recreate the heart muscle.

Type 1 diabetes is caused by the destruction of the pancreatic cells that make insulin. These cells might be reintroduced as stem cells.

Parkinson's disease is caused by a loss of cells. In animal experiments stem cells have been shown to reduce symptoms of the disease.

Some of the most notable findings are as follows: (1) organ-specific stem-cell growth and differentiation are stimulated during the reparative phase following transient injury; (2) some organs contain resident marrow-derived stem cells, and their differentiation potential may only be expressed during repair; (3) the metanephric mesenchyme contains pluripotent and self-renewing stem cells; (4) epithelial-to-mesenchymal transition generates renal fibroblasts, etc (Oliver, 2004).

Stem cell researches are developing very fast. As an example in Korea, after the claims of the first cloning of patient-specific stem cells using somatic nuclear transfer as published in Science in 2004 and 2005, former Seoul National University Professor Woo Suk Hwang became a national hero of Korea and an international celebrity. His academic reputation was down after January 11, 2006 when a nine-member investigation panel at Seoul National University reported that his data were intentionally fabricated. In spite of these negative effectives from both scientific and non-scientific communities, stem cell research in Korea is bouncing back with better focus and balance as evidenced below. First, the Korean government has been reassuring by vowing to continue to support stem cell research in Korea with a long-term spending plan of $454 million over the next 10 years. This represents an even higher level of funding than before the Hwang scandal. Second, non-government sectors are also continuing to push their plans to support stem cell science. Third, despite concerns and unfounded worries, Korean biologists are performing exceedingly well and continue to publish their results in prestigious international journals (Kwang-Soo Kim, 2007).

Until recently, scientists primarily worked with two kinds of stem cells from animals and humans: embryonic stem cells and non-embryonic somatic or adult stem cells. In 2006, it was made another breakthrough by identifying conditions that would allow some specialized adult cells to be "reprogrammed" genetically to assume a stem cell-like state, which is named induced pluripotent stem cells (iPSCs).

In the 3- to 5-day-old embryo (blastocyst), the inner cells give rise to the entire body of the organism, including all of the many specialized cell types and organs such as the egg, sperm, skin, heart, lung, etc.

Stem cells offer new potentials for treating diseases such as diabetes, and heart disease. Adult stem cells typically generate the cell types of the tissue in which they reside. For example, a blood-forming adult stem cell in the bone marrow normally gives rise to the many types of blood cells.

The dividing of stem cell is through the processing of mitosis.

The embryonic stem cells come from the inner cell mass of blastocysts, and adult stem cells are found in various tissues. Stem cells and progenitor cells plays the important roles in the repair schedule of the animal body.

The blastocyst is a structure formed in the early development of mammals. In humans, normally its formation begins at 5 days after fertilization during the germinal stage of development. It possesses an inner cell mass (ICM) which subsequently forms the embryo. The outer layer of cells of the blastocyst is called the trophoblast, which surrounds the inner cell mass and a fluid-filled cavity known as the blastocoel. The trophoblast gives rise to the placenta.

The human blastocyst comprises 200-300 cells following rapid cleavage throughout this stage. This group of cells embeds itself into the endometrium of the uterine wall where it will undergo later developmental processes, including gastrulation.

The use of blastocysts in in-vitro fertilization (IVF) involves culturing a fertilized egg for five days before implanting it into the uterus. It can be a more viable method of fertility treatment than traditional IVF.

Trophoblasts are cells forming the outer layer of a blastocyst, which provide nutrients to the embryo and develop into a large part of the placenta. They are

formed during the first stage of pregnancy and are the first cells to differentiate from the fertilized egg. This layer of trophoblasts is also collectively referred to as "the trophoblast" or, after gastrulation, the trophectoderm, as it is then contiguous with the ectoderm of the embryo.

Trophoblasts are specialized cells of the placenta that play an important role in embryo implantation and interaction with the decasualized maternal uterus. The core of placental villi contains mesenchymal cells and placental blood vessels that are directly connected to the fetal circulation via the umbilical cord. This core is surrounded by two layers of trophoblast; a single layer of mononuclear cytotrophoblast that fuse together to form the overlying multinucleated syncytiotrophoblast layer that covers the entire surface of the placenta. It is this syncytiotrophoblast that is in direct contact with the maternal blood that reaches the placental surface, and thus facilitates the exchange of nutrients, wastes and gases between the maternal and fetal systems.

Glossary related to Stem Cells

- Adult stem cell — Also called somatic stem cell. Stem cells organs and differentiated tissues with a limited capacity for differentiation.
- Astrocyte — A supporting (glial) cell in the nervous system.
- Blastocoel — The fluid-filled cavity inside the blastocyst, an early, preimplantation stage of the developing embryo.
- Blastocyst — A preimplantation embryo, sphere, made up of an outer layer of cells (trophoblast), a fluid-filled cavity (blastocoel), and a cluster of cells on the interior (inner cell mass).
- Bone marrow stromal stem cells (skeletal stem cells)—A multipotent subset of bone marrow stromal cells able to form bone, cartilage, stromal cells that support blood formation, fat, and fibrous tissue.
- Cell culture—Growth of cells in vitro.
- Cell division—A single cell divides to create two cells.
- Chromosome—The DNA molecule in the nucleus of the cell that contains genes. The number of chromosomes in the nucleus varies depending on the species of the organism.
- Clone—To generate identical copies of a region of a DNA molecule or to generate genetically identical copies of a cell, or organism.
- Culture medium—The liquid that covers cells in a culture dish and contains nutrients and factors to nourish and support the cells.
- Differentiation—The process whereby an unspecialized embryonic cell acquires the features of a specialized cell such as a heart, liver, or muscle cell.
- DNA—Deoxyribonucleic acid, a chemical found primarily in the nucleus of cells.
- Ectoderm—The outermost germ layer of cells derived from the inner cell mass of the blastocyst; gives rise to the nervous system, sensory organs, skin, and related structures.
- Embryo—The developing organism from the time of fertilization until the birth.
- Embryonic germ cells—Pluripotent stem cells that are derived from early germ cells. Embryonic stem cells—Undifferentiated cells that are derived from preimplantation-stage embryos, are capable of dividing without differentiating for a prolonged period in culture, and are known to develop into cells and tissues of the three primary germ layers.
- Endoderm—The innermost layer of the cells derived from the inner cell mass of the blastocyst.
- Enucleated—Nucleus removed.
- Epigenetic—Having to do with the process by which regulatory proteins can turn genes on or off in a way that can be passed on during cell division.
- Feeder layer—Cells used in co-culture to maintain pluripotent stem cells.
- Fertilization—The joining of the male gamete (sperm) and the female gamete (egg).
- Fetus—In humans, the developing human from approximately eight weeks after conception until the time of its birth.
- Gamete—An egg or sperm cell.
- Gastrulation—The process in which cells proliferate and migrate within the embryo to transform the inner cell mass of the blastocyst stage into an embryo containing all three primary germ layers.
- Gene—A functional unit of heredity that is a segment of DNA found on chromosomes in the nucleus of a cell.
- Germ layers—After the blastocyst stage of embryonic development, the inner cell mass of the blastocyst goes through gastrulation, a period when the inner cell mass becomes organized into three distinct cell layers, called germ layers.
- Hematopoietic stem cell—A stem cell that gives rise to all red and white blood cells and platelets.
- Human embryonic stem cell (hESC)—A type of pluripotent stem cell derived from early-

stage human embryos, up to and including the blastocyst stage. hESCs are capable of dividing without differentiating for a prolonged period in culture and are known to develop into cells and tissues of the three primary germ layers.

- Induced pluripotent stem cell (iPSC)—A type of pluripotent stem cell, similar to an embryonic stem cell, formed by the introduction of certain embryonic genes into a somatic cell.
- In vitro—In a laboratory dish or test tube; an artificial environment.
- Inner cell mass (ICM)—The cluster of cells inside the blastocyst. These cells give rise to the embryo and ultimately the fetus.
- Long-term self-renewal—The ability of stem cells to renew themselves by dividing into the same non-specialized cell type over long periods (many months to years) depending on the specific type of stem cell.
- Mesenchymal stem cells—A term that is currently used to define non-blood adult stem cells from a variety of tissues, although it is not clear that mesenchymal stem cells from different tissues are the same.
- Meiosis—The type of cell division a diploid germ cell undergoes to produce gametes (sperm or eggs) that will carry half the normal chromosome number.
- Mesoderm—Middle layer of a group of cells derived from the inner cell mass of the blastocyst; it gives rise to bone, muscle, connective tissue, kidneys, and related structures.
- Microenvironment—The molecules and compounds such as nutrients and growth factors in the fluid surrounding a cell in an organism or in the laboratory, which play an important role in determining the characteristics of the cell.
- Mitosis—The type of cell division that allows a population of cells to increase its numbers or to maintain its numbers. The number of chromosomes remains the same in this type of cell division.
- Multipotent—Having the ability to develop into more than one cell type of the body.
- Neural stem cell—A stem cell found in adult neural tissue that can give rise to neurons and glial (supporting) cells. Examples of glial cells include astrocytes and oligodendrocytes.
- Neurons—Nerve cells, the principal functional units of the nervous system. A neuron consists of a cell body and its processes—an axon and one or more dendrites. Neurons transmit information to other neurons or cells by releasing neurotransmitters at synapses.
- Oligodendrocyte—A supporting cell that provides insulation to nerve cells by forming a myelin sheath (a fatty layer) around axons.
- Parthenogenesis—The artificial activation of an egg in the absence of a sperm; the egg begins to divide as if it has been fertilized.
- Passage—In cell culture, the process in which cells are disassociated, washed, and seeded into new culture vessels after a round of cell growth and proliferation. The number of passages a line of cultured cells has gone through is an indication of its age and expected stability.
- Pluripotent—The state of a single cell that is capable of differentiating into all tissues of an organism, but not alone capable of sustaining full organism development. Scientists demonstrate pluripotency by providing evidence of stable developmental potential, even after prolonged culture, to form derivatives of all three embryonic germ layers from the progeny of a single cell and to generate a teratoma after injection into an immunosuppressed mouse.
- Polar Body—A polar body is a structure produced when an early egg cell, or oogonium, undergoes meiosis. In the first meiosis, the oogonium divides its chromosomes evenly between the two cells but divides its cytoplasm unequally. One cell retains most of the cytoplasm, while the other gets almost none, leaving it very small. This smaller cell is called the first polar body. The first polar body usually degenerates. The ovum, or larger cell, then divides again, producing a second polar body with half the amount of chromosomes but almost no cytoplasm. The second polar body splits off and remains adjacent to the large cell, or oocyte, until it (the second polar body) degenerates. Only one large functional oocyte, or egg, is produced at the end of meiosis.
- Preimplantation—With regard to an embryo, preimplantation means that the embryo has not yet implanted in the wall of the uterus. Human embryonic stem cells are derived from preimplantation stage embryos fertilized outside a woman's body (in vitro).
- Proliferation—Expansion of the number of cells by the continuous division of single cells into two identical daughter cells.
- Regenerative medicine—A field of medicine devoted to treatments in which stem cells are induced to differentiate into the specific cell type required to repair damaged or destroyed

cell populations or tissues. See also cell-based therapies.

- Reproductive cloning—The process of using somatic cell nuclear transfer (SCNT) to produce a normal, full grown organism (e.g., animal) genetically identical to the organism (animal) that donated the somatic cell nucleus. In mammals, this would require implanting the resulting embryo in a uterus where it would undergo normal development to become a live independent being. The first animal to be created by reproductive cloning was Dolly the sheep, born at the Roslin Institute in Scotland in 1996. See also Somatic cell nuclear transfer (SCNT).
- Signals—Internal and external factors that control changes in cell structure and function. They can be chemical or physical in nature.
- Somatic cell—Any body cell other than gametes (egg or sperm); sometimes referred to as "adult" cells. See also Gamete.24
- Somatic cell nuclear transfer (SCNT)—A technique that combines an enucleated egg and the nucleus of a somatic cell to make an embryo. SCNT can be used for therapeutic or reproductive purposes, but the initial stage that combines an enucleated egg and a somatic cell nucleus is the same. See also Therapeutic cloning and Reproductive cloning.
- Somatic (adult) stem cell—A relatively rare undifferentiated cell found in many organs and differentiated tissues with a limited capacity for both self renewal (in the laboratory) and differentiation. Such cells vary in their differentiation capacity, but it is usually limited to cell types in the organ of origin. This is an active area of investigation.
- Stem cells—Cells with the ability to divide for indefinite periods in culture and to give rise to specialized cells.
- Stromal cells—Connective tissue cells found in virtually every organ. In bone marrow, stromal cells support blood formation.
- Subculturing—Transferring cultured cells, with or without dilution, from one culture vessel to another.
- Surface markers—Proteins on the outside surface of a cell that are unique to certain cell types and that can be visualized using antibodies or other detection methods.
- Teratoma—A multi-layered benign tumor that grows from pluripotent cells injected into mice with a dysfunctional immune system. Scientists test whether they have established a human embryonic stem cell (hESC) line by injecting putative stem cells into such mice and verifying that the resulting teratomas contain cells derived from all three embryonic germ layers.
- Therapeutic cloning—The process of using somatic cell nuclear transfer (SCNT) to produce cells that exactly match a patient. By combining a patient's somatic cell nucleus and an enucleated egg, a scientist may harvest embryonic stem cells from the resulting embryo that can be used to generate tissues that match a patient's body. This means the tissues created are unlikely to be rejected by the patient's immune system. See also Somatic cell nuclear transfer (SCNT).
- Totipotent—The state of a cell that is capable of giving rise to all types of differentiated cells found in an organism, as well as the supporting extra-embryonic structures of the placenta. A single totipotent cell could, by division in vitro, reproduce the whole organism.
- Transdifferentiation—The process by which stem cells from one tissue differentiates into cells of another tissue.
- Trophoblast—The outer cell layer of the blastocyst. It is responsible for implantation and develops into the extraembryonic tissues, including the 25
- placenta, and controls the exchange of oxygen and metabolites between mother and embryo.
- Umbilical cord blood stem cells—Stem cells collected from the umbilical cord at birth that can produce all of the blood cells in the body (hematopoietic). Cord blood is currently used to treat patients who have undergone chemotherapy to destroy their bone marrow due to cancer or other blood-related disorders.
- Undifferentiated—A cell that has not yet developed into a specialized cell type.

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