Stem Cells: Where the Future Lies

Dr.Shantanu Khattri
M.D.S.
Faculty, Dept of Orthodontics,
Career P.G. Institute of Dental Sciences, Lucknow
drshantanukhattri@rediffmail.com

Dr.Madhvi Bhradwaj
M.D.S.
Faculty, Dept of Orthodontics,
Career P.G. Institute of Dental Sciences, Lucknow

Introduction:

Research on stem cells is advancing knowledge about how an organism develops from a single cell and how healthy cells replace damaged cells in adult organisms.

Stem cells are one of the most fascinating areas of biology today. Stem cells promise to be a powerful technology that can't be ignored.

Stem cells:

Most of the 300 trillion cells of the body have completely specialized functions. Blood, lung, brain, skin or liver cells are all wonderfully specialized for what they do. By and large, they cannot do anything other than what they were designed for.

On the other hand, the term stem cell is reserved for "undifferentiated cells with the capacity for self renewal and the ability to produce one highly differentiated progenitor". They exist mainly to maintain and repair cells in the areas where they are found. Stem cells are

found in the blood, bone marrow, muscle, skin, and organs like the brain and liver.

There are basically two types of stem cells:

(1) Embryonic stem cells

(2) Adult stem cells

Human embryonic stem cells are derived from fertilized embryos less than a week old. After sperm fertilizes an egg, a zygote is formed which then has the potential to develop into a complete embryo. At this point, the fertilized egg is a totipotent stem cell, which means that it has the potential to create any type of cell necessary for embryonic development (this includes extra embryonic membranes and tissues, the embryo itself, and all post embryonic tissues and organs).

In the first few hours after fertilization, the fertilized egg undergoes several cell divisions that produce identical totipotent cells. Because these cells are still totipotent, it means that any one of these cells has the potential to develop into an entire human being.

The totipotent cells undergo several rounds of cell division. Approximately four days after fertilization, they begin to specialize and form a blastocyst. A blastocyst is a ball of cells consisting of a hollow outer layer of cells call the inner cell mass.

The outer layer of cells will eventually form the placenta and other tissues that are needed for the support and development of the fetus. These inner cell mass cells are pluripotent. This means that they are able to give rise to many, but not all cell types necessary for fetal development (e.g., they are able to give rise to fetal tissues, but not placental tissue). It is this pluripotent stem cell that is currently under investigation for medical use.

The pluripotent cells then further specialize into another type of stem cell, a multipotent stem cell. Multipotent stem cells are committed to give rise to cells that have a particular function, e.g., blood stem cells

give rise to red blood cells, white blood cells and platelets, and skin stem cells give rise to the different types of skin cells. Multipotent stem cells exist in both humans and adults, the best example being the blood stem cell.

How do stem cells differ from other cells in the body? Or Unique properties of all stem cells:

All stem cells, regardless of their source, have three general properties, which make them different from other cells in the body:

(1) They are capable of dividing and renewing themselves for long periods:

Unlike muscle cells, blood cells, or nerve cells – which normally do not replicate themselves – stem cells may replicate many times, called proliferation. A starting population of stem cells that proliferates for many months in the laboratory can yield millions of cells. If the resulting cells continue to be unspecialized, like the parent stem cells, the cells are said to be capable of long-term self-renewal.

(2) They are unspecialized:

One of the fundamental properties of a stem cell is that it does not have any tissue-specific structures that allow it to perform specialized functions. However, unspecialized stem cells can give rise to specialized cells, including heart muscle cells, blood cells, or nerve cells.

(3) They can give rise to specialized cell types:

When unspecialized stem cells give rise to specialized cells, the process is called differentiation. Scientists are just beginning to

understand the signals inside and outside cells that trigger stem cell differentiation.

Embryonic stem cells:

Embryonic stem cells as their name suggests, are derived from embryos. Specifically, embryonic stem cells are derived from embryos that develop from eggs that have been fertilized in vitro–in an invitrofertilization clinic, and then donated for research purposes with informed consent of the donors. They are not derived from the eggs fertilized in a woman's body.

In 1998, James Thompson of the University of Wisconsin-Madison proved that embryonic stem cells can be sustained indefinitely in the laboratory, creating hundreds of generations of identical stem cells.

Human embryonic stem cells:

Human embryonic stem cells are cultured cell lines that are derived from the inner cell mass of the blastocyst that can be grown indefinitely in their undifferentiated state, yet also are capable of differentiating into all cells of the adult body. For e.g., they can form muscle cells, nerve cells, and many other types of cells.

Stem cell cultivation:

Stem cells are derived from eggs that have been fertilized in vitro. The embryos from which human embryonic stem cells are derived are typically four or five days old and are a hollow microscopic ball of cells called the blastocyst. The blastocyst includes three structures: the trophoblast, which is the layer of cells that surrounds the blastocyst; the blastocoel, which is the hollow cavity inside the blastocyst; and the inner cell mass, which is a group of approximately 30 cells at one end of the blastocoel. These are the cultured undifferentiated stem cells, which are

capable of differentiating into specialized cells like blood cells, neural cells, muscle cells, etc.

As long as the embryonic stem cells in culture are grown under certain conditions, they can remain undifferentiated (unspecialized). But if the cells are allowed to clump together to form embryoid bodies, they begin to differentiate spontaneously to form specialized structures.

Advantages of embryonic stem cells:

(1) They are flexible.

(2) They are easily available.

Disadvantages of embryonic stem cells:

Inspite of its various advantages, embryonic stem cells have certain disadvantages also. They are:

(1) It is hard to control its growth.

(2) It is ethically controversial to use human embryos.

(3) It is rejected by the immune system of the human body.

Adult stem cells:

The history of research on adult stem cells began about 40 years ago. Adult stem cells are undifferentiated cells found among differentiated cells of a specific tissue or organ. These stem cells can renew themselves and can differentiate to yield the major specialized cell types of the tissue or organ. They are mostly multipotent cells. They are already being used in treatments for over one hundred diseases and conditions. The primary roles of adult stem cells in a living organism are to maintain and repair the tissue in which they are found. The origin of adult stem cells in mature tissues is unknown. E.g., hematopoietic stem cells,

bone marrow stromal cells, neural stem cells, skin stem cells that occur in the basal layer of the epidermis and at the base of hair follicles.

In a living animal adult stem cell, that are mostly multipotent cells, can divide for a long period and can give rise to mature cell types that have characteristic shapes and specialized structures and functions of a particular tissue like neural cells, cardiac muscles etc.

Advantages of adult stem cells:

Following are the examples of adult stem cells:

(1) They are immune to immunological attack.
(2) They are partly specialized.
(3) They are flexible in their nature as they may form other types of tissues.

Disadvantages of adult stem cells:

Following are the disadvantages of adult stem cells:

(1) They are very scarce in nature because all types have not been found yet.
(2) They are vanishing in nature, as they don't live long.
(3) They are very rare.

Future applications of stem cells:

Stem cells are of wide interest for medicine because they have the potential, under suitable conditions, to develop into almost all of the different types of cells. Embryonic stem cells have not yet been used for even one therapy, while adult stem cells have already been successfully used in numerous patients. Certain kinds of adult stem cells seem to have the ability to differentiate into a number of different cell types, given the right conditions. If this differentiation of adult stem cells can be controlled

in the laboratory, these cells may become the basis of therapies for many serious common diseases including cardiac infarction.

Scientists in many laboratories are trying to find ways to grow adult stem cells in cell culture and manipulate them to generate specific cell types so they can be used to treat injury or disease.

Some of the examples of potential treatment include:

(1) Replacing the dopamine-producing cells in the brains of Parkinson's patient.
(2) Developing insulin producing cells for Type I Diabetes.
(3) Repairing damaged heart muscle following a heart attack with cardiac muscle cells.

Various other examples of potential treatment also exist other than those listed above.

The promise of stem cell research:

Many research procedures in the field of stem cells are going at a faster pace and some day it will revolutionize the field of medicine.

The cultured pluripotent stem cells can be used for the drug development and toxicity tests, for the experiments to study development and gene control, for the tissues or cells for therapy.

Conclusion:

Till today, certain questions like why embryonic stem cells can proliferate for a year or more in the laboratory without differentiating, but most adult stem cells cannot; what are the factors in living organisms that normally regulate stem cell proliferation and self-renewal; and many more still remain unanswered.

Discovering the answers to these questions may make it possible to understand how cell proliferation is regulated during normal

embryonic development or during the abnormal cell division that leads to cancer.