Stem Cells

Q: What are stem cells?

A: Stem cells are the foundation cells for every organ, tissue and cell in the body. They are like a blank microchip that can ultimately be programmed to perform any number of specialized tasks. Stem cells are undifferentiated, “blank” cells that do not yet have a specific function. Under proper conditions, stem cells begin to develop into specialized tissues and organs. Additionally, stem cells are self-sustaining and can replicate themselves for long periods of time.

These unique characteristics make stem cells very promising for supplying cells to treat debilitating diseases like Parkinson's disease, cancer, type-1 diabetes, spinal cord injury, stroke, burns, heart disease, osteoarthritis and rheumatoid arthritis. Today, donated organs and tissues are often used to replace those that are diseased or destroyed. Unfortunately, the number of people needing transplants far exceeds the number of organs available. Stem cells offer the potential for supplying cells and tissues, which can be used to treat these various diseases.

Q: Where do stem cells come from?

A: All human beings start their lives from a single cell, the fertilized egg, which is also known as a zygote. The zygote divides and forms two cells; each of those cells divides again, and so on. Pretty soon, about five days after conception, there is hollow ball of about 150 cells called the blastocyst. The blastocyst is smaller than a grain of sand and contains two types of cells, the trophoblast and the inner cell mass. Embryonic stem cells are the cells that make up the inner cell mass. As embryonic stem cells can form all cell types in an adult, they are referred to as pluripotent stem cells.

Stem cells can also be found in very small numbers in various tissues in the adult body. For example, bone marrow stem cells are found in the marrow of the bone and they give rise to all specialized blood cell types. Adult stem cells are typically programmed to form different cell types of their own tissue; they are called multipotent stem cells. Adult stem cells have not yet been identified in all vital organs. In some tissues like the brain, although stem cells exist, they are not very active, and thus do not readily respond to cell injury or damage. Scientists are now also exploring ways in which they can induce the stem cells already present to grow and make the right cell types to replace the damaged ones.

Stem cells can also be obtained from sources like the umbilical cord of a newborn baby. This is an accessible source of stem cells, compared to adult tissues like the brain and bone marrow. Although scientists can grow these cells in culture dishes, they can do so only for a limited time.

Recently, scientists have discovered the existence of stem cells in baby teeth and in amniotic fluid – the "water bath" that surrounds an unborn baby – and these cells may also have the potential to form multiple cell types. Research to characterize and study these cells is very promising but at a very early stage.

Q: What are the potential uses of human stem cells?

A: Most of the body's specialized cells cannot be replaced by natural processes if they are seriously damaged or diseased. Stem cells can be used to generate healthy and functioning specialized cells, which can then replace diseased or dysfunctional cells.

Replacing diseased cells with healthy cells, called cell therapy, is similar to the process of organ transplantation only the treatment consists of transplanting cells instead of organs. Some conditions or injuries can be treated through transplantation of entire healthy organs, but there is an acute shortage of donors. Stem cells can serve as an alternate and renewable source for specialized cells. Currently, researchers are investigating the use of adult, fetal and embryonic stem cells as a resource for various, specialized cell types, such as nerve cells, muscle cells, blood cells and skin cells that can be used to treat various diseases.

For example, in Parkinson's disease, stem cells may be used to form a special kind of nerve cell, a kind that secretes dopamine. These nerve cells can theoretically be transplanted into a patient where they will re-wire the brain and restore function, thus treating the patient.

Q: What are the obstacles that must be overcome before the potential uses of stem cells will be realized?

A: One of the first obstacles that must be overcome is the difficulty in identifying stem cells from adult tissues, which contain numerous mixtures of various cells. The process of identifying and growing the right kind of stem cell, usually a very rare cell in the adult tissue, involves painstaking research.

Second, once stem cells are identified and isolated, the right conditions must be developed to cause these cells to differentiate into the specialized cells. This too will require a great deal of experimentation.

In general, embryonic and fetal stem cells are believed to be more versatile than adult stem cells. However, scientists are still working on developing proper conditions to differentiate embryonic stem cells into specialized cells. As embryonic stem cells grow very fast, scientists must be very careful in fully differentiating them into specialized cells. Otherwise, any remaining embryonic stem cells can grow uncontrolled and form tumors.

Assuming that the above obstacles can be overcome, new issues arise when the specialized cells (grown from stem cells) are implanted into a person. The cells must be integrated into the patient's own tissues and organs and "learn" to function in concert with the body's natural cells. Cardiac cells that beat in a cell culture, for example, may not beat in rhythm with a patient's own heart cells. And neurons injected into a damaged brain must become "wired into" the brain's intricate network of cells and their connections in order to work properly.

Yet another challenge is the phenomenon of tissue rejection. Just as in organ transplants, the body's immune cells will recognize transplanted cells as "foreign," setting off an immune reaction that could cause the transplant to fail and possibly endanger the patient. Cell recipients would have to take drugs to temporarily suppress their immune systems, which in itself could be dangerous.

Thus, research on stem cells and their applications to treat various diseases is still at a preliminary stage. However, results from animal models are very promising and many researchers believe that it is only a matter of time before the same results can be achieved with human stem cells.

Q: What is an embryonic stem cell?

A: Embryonic stem cells are derived from the cells that make up the inner cell mass of the blastocyst. Both mouse and human embryonic stem cell lines exist. Mouse embryonic stem cells are capable of generating any and all cells in the body, under the right conditions. Therefore, they are said to be pluripotent and have unlimited potential as far as growth and differentiation. The cells divide continuously in tissue culture dishes in an incubator, but at the same time maintain the ability to generate any cell type when placed into the correct environment to cause their differentiation.

Human embryonic stem cell lines are currently being studied and several research teams are working to determine whether or not they possess the same properties as mouse embryonic stem cells. Because human embryonic stem cells were isolated relatively recently, and therefore we know less about them, it is currently more difficult to work with human systems than mouse. However, scientists are making remarkable progress that could ultimately lead to therapies to replace or restore damaged tissues using these human cells.

Q: What is an adult stem cell?

A: Adult stem cells are distinct from cells isolated from embryos or fetuses and are found in tissues that have already developed, as in animals or humans after birth. These cells can be isolated from many tissues, including brain. However, the most common place to obtain these cells is from the bone marrow that is located in the center of some bones. The marrow is harvested from human donors at the iliac crest (the back of the upper hip bone).

There are different types of stem cells found in the bone marrow, including hematopoietic stem cells, endothelial stem cells, and mesenchymal stem cells. It has long been known that hematopoietic stem cells form blood, endothelial stem cells form the vascular system (arteries and veins), and mesenchymal stem cells form bone, cartilage, muscle, fat, and fibroblasts.

In recent years, a theory of "stem cell plasticity" has been put forth, which suggests that some adult stem cells may have a broader potential to form different cell types than was previously suspected. That means cells from the bone marrow, originally thought to be purely blood-forming cells, may contribute to regeneration of damaged livers, kidneys, hearts, lungs and other organs.

More recently, scientists have managed to reprogram human "somatic" cells, which have already assumed a specialized role in the body, giving these cells many of the characteristics of embryonic stem cells. Ultimately, the hope is that these "induced pluripotent stem cells," or "iPS cells," could be used to generate genetically matched healthy cells to replace diseased ones.

Although this field is extremely exciting, it will require additional, carefully documented research to understand the full potential of the adult stem cells, and in particular how they compare to embryonic stem cells, AAAS has said. In a December 2007 op-ed in the *Washington Post*, for example, stem-cell pioneer James Thomson and Leshner said that alternative approaches are "only a first step on the long road toward eventual therapies."

Q: What is unique about stem cells from baby teeth or umbilical cords?

A: Stem cells from umbilical cord blood or the pulp under baby teeth are "younger" stem cells than those obtained from adults. They are able to divide for longer times in cell cultures than most adult stem cells, and may give rise to different tissues. Their potential to form many different cell types is currently being explored.

Umbilical cord blood stem cells are used for stem cell transplantation to reconstitute blood cell formation (the hematopoietic system) in patients that have been irradiated or treated with specific drugs for cancer or leukemia. Also, in some genetic diseases, where patients have a problem forming normal blood cells, a transplantation of matched umbilical cord blood cells can give them a new blood-forming system.

The new cells are infused into the vein of the patient and then they are able to find their way into the bone marrow, in a process called "stem cell homing."