

Stem cells: The future of medicine?



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ABSTRACT

Stem cells are one of the brightest hopes for the future of modern medicine. It is thought that it is possible to use them to cure a vast array of illnesses and disorders, ranging from diabetes, to Parkinson's disease and even to help the sufferers of trauma, such as those with spinal damage. Stem cells are unspecialized cells which have the potential to specialize into many different types of cell. The number of different cells into which they can specialize depends on their potency, with embryonic stem cells having the most potential (totipotent). These embryonic stem cells are first formed when a sperm cell fertilizes an egg cell. From this single cell all the cells in your body are descended.

Stem cells are different from all the other cells in our body. Specialized cells, for example red blood cells, are known as differentiated cells - they have a particular function. Stem cells, however, are undifferentiated and thus do not have a particular role in the body. They have three general properties:

- They are able to divide (proliferate)/renew themselves for long periods.
- They are unspecialized.
- They give rise to specialized cells.

Stem cells start development when a sperm and an egg meet. This produces a 'special' stem cell that has the potential to grow into a human being and a placenta that will feed the embryo as it grows.

When the cell starts to divide each cell is still undifferentiated. However, after a certain point of development a series of signals limit each cell's potential. This is when differentiation has begun [Figure 1]. One week after fertilization, the embryo is known as the blastocyst. The cells on the outside

of the wall will form the placenta, and the cells on the inside (the inner mass) will form all the cells in the body.^[1]

Two weeks after fertilization, the cells of the embryo organize into three layers. Cell signals restrict the potential of these cells even further; each layer will produce a different set of cell types. After a few weeks each layer forms the following:

- Ectoderm (outer layer) becomes the skin, nervous system, and parts of the face and neck
- The mesoderm (middle layer) becomes muscle, blood, blood vessels, bones, and connective tissue.
- The endoderm (inner layer) becomes the digestive and respiratory tracts and the glands that feed them - including the pancreas and liver.

After being born, we still maintain areas of stem cells; these somatic stem cells play a very important role in growth, maintenance, and repair. Figure 2 indicates the areas where these stem cells are found in the body.

Adult stem cells mostly remain dormant, waiting for a signal to tell them to divide. But some stem cells are constantly replacing the cells that are lost every day. The somatic (adult) stem cells are different from embryonic stem cells as under normal conditions they can only produce a few cell types. For example, the bone marrow produces blood cells, like red blood cells. Bone marrow has many somatic stem cells next to many differentiated cells.

Multipotent, Pluripotent, Totipotent and Unipotent Stem Cells

Pluripotent cells have the ability to make all the different cell types in the body; however, they cannot make extra embryonic tissues like the placenta. Multipotent cells have the ability to develop into more than one cell type in the body. Totipotent cells have the ability to develop into all the cell types in the body including those embryonic tissues like the placenta. Unipotent cells have the ability to differentiate into only one cell type, for example: hepatocytes in the liver.^[2]

The Concerns and Controversy Surrounding the Use of Stem Cells

The main controversy surrounding stem cells are that one must use an embryo to obtain stem cells.^[3] Clearly, there are many moral implications associated with using egg cells. Some believe that potential life is effectively being killed to help save someone else's. There are other methods like iPSC, which are still in the early developing stages.^[4]

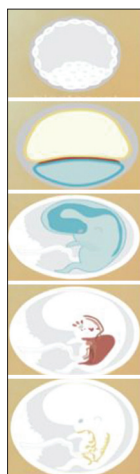


Figure 1: The development of an embryo [Available from: <http://www.learn.genetics.utah.edu/content/tech/stemcells>]

In 2006, Shinya Yamanaka, in Japan, discovered induced pluripotent stem cells (iPSCs); these cells were created from ordinary skin cells. By using embryonic stem cells, he localized the particular genes that had to be switched 'on' to make stem cells. Each cell in our body has the same 20,000 genes but a heart cell is different from a liver cell due to which genes are switched on and switched off. This is known as cell programming.

Yamanaka reduced these several million possibilities to just four genes after three years of research. He did this by testing each gene's ability to make pluripotent stem cells. This achievement allowed him to turn adult cells, like skin cells, into stem cells. However, there are still some problems with this method:

- The virus used to transfer the four genes into a skin cell can mutate the whole DNA and cause cancer.
- One of the four genes is a gene that is known to cause cancer.
- A high percentage of the mice used to test this gene did develop cancer.

However, research has been done to remove this cancer-causing gene immediately after it had served its beneficial purpose of creating pluripotent stem cells. This method has been tested and cured mice with sickle cell anemia. There is still a lot of controversy surrounding this method and, therefore, the preferred method is to use embryonic stem cells.

The Use of Stem Cells

Further research into stem cells has the potential to open up a wide range of exciting new possibilities,



Figure 2: Where are stem cells found in the body? [Available from: <http://www.learn.genetics.utah.edu/content/tech/stemcells/scintro/>]

both within the medical world and in other areas.^[5] Their unique properties allow them to be used in a variety of different ways to cure a wide range of illnesses, ranging from diabetes to leukemia.^[6]

Diabetes

Type 1 Diabetes is caused by the immune system mistakenly attacking the insulin producing beta cells in the pancreas. Insulin is the hormone that is involved in the regulation of glucose levels within the blood. It works by binding to an insulin receptor on a cell (mainly in adipose tissue and striated muscle), which causes a cascade of reactions that causes more GLUT4 (Glucose Transporter Type 4) proteins to move to the plasma membrane. This, in turn, allows for a greater rate of transport of glucose into the cell, thus taking glucose out of the blood. It can also lead to the synthesis of glycogen from glucose molecules to act as a form of energy storage. When the beta cells are attacked, this leads to depletion of insulin, which prevents gluco-regulation from taking place. This can lead to glucose levels in the blood rising to dangerous, and possibly fatal, levels. Current treatment for diabetes involves consistent injections of insulin and the regulation of diet to maintain a healthy level of glucose in the blood. Another form of treatment would be a pancreas transplant to give the patient new beta cells. However, there is currently a shortage of pancreases available for transplant, and there are also other issues involved with transplants such as the need for antirejection drugs.

Research into stem cells could yield the exciting new possibility of being able to grow a new pancreas from embryonic stem cells. This would solve the issue of lack of organ donors, since the organs could be grown to meet the demand. Another potential would be to use induced pluripotent stem cells. This involves reprogramming the patient's own somatic cells into becoming pluripotent stem cells, which can then be used to grow a new organ. This would solve the problem of organ rejection since the pancreas would have been grown from the patient's own cells and so would not be viewed by the immune system as being foreign. This would mean that immune-suppressant drugs would no longer be necessary and so there would no longer be the problem of increased susceptibility to infection that is the inevitable result of a suppressed immune system. Much research has been carried out in this area, however, these types of pancreas that are implanted into mice are shown to produce less insulin than pancreases that have been transplanted normally, from a donor. There is also

the issue of the original problem, that of the immune system mistakenly attacking the beta cells, can still occur. Perhaps this defeats the purpose of using a method that attempts to avoid organ rejection.

Trachea transplant

The principle of growing organs from stem cells can be extended to many different organs other than the pancreas. One highly successful operation is that of the trachea transplant. An artificial structure of the windpipe of the patient can be made, or a donor trachea can be stripped of the cells, leaving only the cartilaginous structure behind. This structure can then be coated with the patient's own stem cells, which grow on the structure to form a fully functioning transplant. The advantage of using an artificial structure is that it requires no donor at all, and the replacement trachea can be made within days.

Leukemia

Stem cells are already used in the treatment of leukemia. It involves the transplant of hematopoietic cells from the bone marrow into the patients that can go on to produce new white blood cells.

The nervous system

Stem cells can be used to regenerate nerve tissue damaged by trauma. A person with a broken back may be able to be treated so that they can walk again. This would be achieved by growing nerve cells from the patient's cells to reconnect the severed ends of the spinal cord.

There is also the potential for a cure to Parkinson's disease. Parkinson's damages a single, well-identified, dopamine-producing cell in the brain. These are located in a specific part of the brain known as the *substantia nigra*. Stem cells could be transplanted into this region, and being able to produce dopamine, could relieve the patient of the debilitating effects of the disease.

Growing meat

Recently, there has been talk of scientists being able to encourage stem cells to grow into muscle cells that could be used for food. If the process were to be made cheaper and faster, then, this could be an effective form of food production and could also appeal to vegetarians since no animals would be harmed in the process. However, if you want a burger made from these stem cells anytime soon you are going to have to start saving up approximately £200,000!^[5]

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