Introduction to Stem Cells

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In recent years, stem cells have been at the center of attention of scientists and researchers because of their immense potential in the medical field. Their uses include but are not limited to cell therapy, organ transplant and drug testing. They are all thanks to stem cells' unique ability to differentiate.

Stem cells are cells that are undifferentiated. They are the body's raw materials. They are located in their corresponding stem cell niches, which are areas of tissue that provide specific microenvironments for the stem cells to maintain a self-renewable and undifferentiated state, which are their two essential properties (Mayo Foundation, 2022).

Being able to self-renew means that stem cells can undergo cell growth and division in their undifferentiated state through mitosis. They also use two additional mechanisms to do so. The first is asymmetric cell division, where the mother cell gives rise to two distinct daughter cells: one stem cell and one cell that is programmed to differentiate. The second is stochastic differentiation, where one stem cell produces two undifferentiated daughter cells once another one's daughter cells become differentiated (He et al., 2009).

Additionally, stem cells must have the ability to differentiate into specialized cells. The term potency refers to the cell's differentiation potential. There are 8 types of stem as described below:

1. Totipotent stem cells

Totipotent stem cells have the highest potency. These cells alone can construct an entire organism. They can be found in fertilized eggs as well as early embryonic tissues, and they can differentiate into any cells of the body. Only the embryonic cells within the first few cell divisions after they have been fertilized are totipotent. This early stage of the embryo is called the morula, which appears just a few days after fertilization occurs. However, as the zygote develops, the stem cells become less and less potent as they begin to differentiate. (MacDonald, 2018).

2. Pluripotent stem cells

Pluripotent stem cells come from these totipotent cells. They can differentiate into cells from any of the three germ layers - the endoderm, mesoderm, and ectoderm lines. They are found in the blastocyst, which is another early stage of the embryo, after the morula. In mammals, about 50 to 150 cells make up the blastocyst's inner cell mass. (MacDonald, 2018).

3. Multipotent stem cells

There are three major multipotent stem cells including neutral, mesenchymal, and hematopoietic stem cells. They are able to differentiate into a limited range of cell types that are closely related to each other. Neural stem cells will differentiate into neurons, oligodendrocytes, and astrocytes; Mesenchymal stem cells will be able to differentiate into fat, cartilage, and bone. Hematopoietic stem cells are able to differentiate to all types of blood cell including red blood cell, while blood cell and platelets. They are found in many locations of the body, such as bone marrow, brain and connection tissue such as fat (Rajabzadeh et al., 2019).

4. Oligopotent stem cells

They are more limited than multipotent stem cells, though they can also differentiate into a number of cell types. Lymphoid and myeloid stem cells are examples of oligopotent stem cells. A lymphoid cell, for instance, can differentiate into B and T cells, but not into another type of blood cell like a red blood cell (Zakrzewski et al., 2019).

5. Amniotic stem cells

Another type of stem cells is amniotic stem cells. They are found in the amniotic fluid as well as umbilical cord blood and are extracted from the amniotic sac. They can develop into many types of tissue such as cartilage, cardiac tissue, and nerves. Along with iPS cells, they help overcome the ethical issue of using embryos as a source for stem cells because they are obtained without harming the embryo (Mayo Foundation, 2022).

6. iPS cells

Scientists have developed induced pluripotent stem cells (iPS cells) from adult cells. Adult cells are not to be confused with adult stem cells; adult cells are actually somatic cells, like epithelial cells. Such cells are genetically reprogrammed with protein transcription factors to give them pluripotent capabilities. Certain genes are added or manipulated so that the reprogrammed cells can maintain their potency. An advantage of iPS cells is that there is no longer the need to obtain embryonic stem cells from embryos, which could be an ethical issue (Mahla, 2016).

The 2012 Nobel Prize in Physiology or Medicine was awarded to John B. Gurdon and Shinya Yamanaka for their discovery that specialized cells can be reprogrammed to stem cells. In 1962, Gurdon discovered the reversibility of cell specialization. He experimented with frogs and replaced the nucleus of an egg cell with that from an intestinal cell. This modified egg cell nevertheless developed into a healthy tadpole. In 2006, Yamanaka was able to reprogram mature cells in mice into pluripotent stem cells by introducing several genes ("The Nobel Prize," 2012).

7. Embryonic stem cells

Stem cells are not only found in the early stages of an organism, but are also found in adults, though embryonic stem cells and adult stem cells have slightly different properties. Embryonic stem cells are cells of the inner cell mass in the blastocyst, as mentioned above. They are pluripotent. As the embryo continues to develop, these cells of the inner cell mass divide repeatedly. Without artificial manipulation or optimal culture conditions, they will become increasingly specialized (Mayo Foundation, 2022).

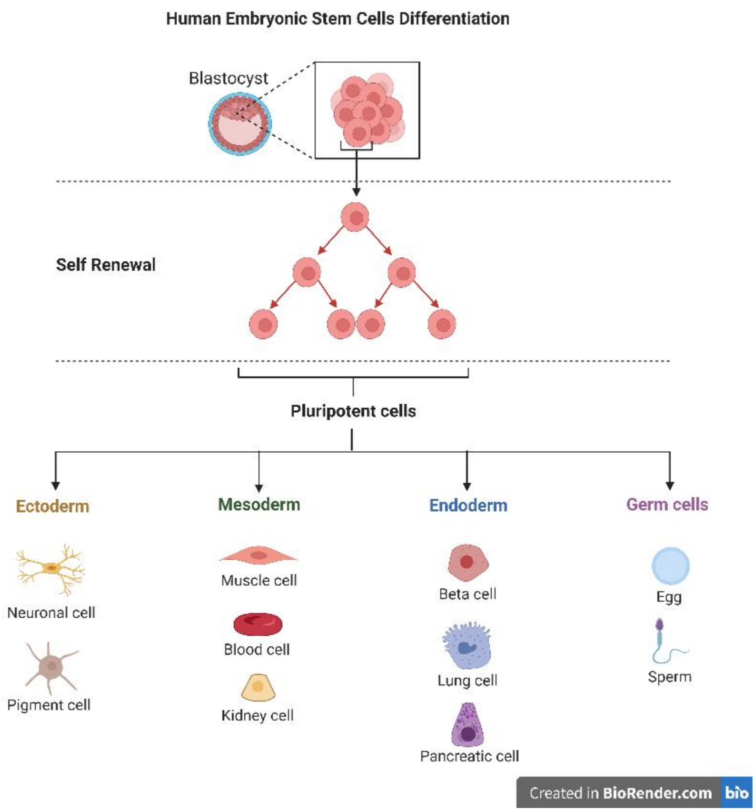

Figure 1. Differentiation of Human Embryonic Stem Cells.

8. Adult stem cells

Unlike embryonic cells, tissue-specific stem cells can be found in the body throughout an individual's life. Adult stem cells are multipotent. Their main function is to maintain and repair damaged tissue. There are three accessible sources in humans from which adult stem cells can be extracted: the bone marrow, body fat, and blood (Mayo Foundation, 2022).

Even though there are no ethical issues around the extraction of adult stem cells, they are not as durable and versatile as embryonic stem cells. They also do not have as much potency, which limits their ability to treat different diseases. Additionally, they are more vulnerable to DNA damage that accumulates with age, which increases stem cell dysfunction (MacDonald, 2018).

Overtime, the demand for stem cells for research and clinical purposes continued to increase. They are used in regenerative medicine, which involves creating healthy cells to replace cells affected by disease. Stem cells have the potential to be grown and become new tissue that can repair damaged tissue. They are also used in transplants. Instead of using donor organs that are limited in supply, specialized stem cells can be implanted into a person and help with the repair of tissue (Mahla, 2016).

Currently, research is still ongoing in hopes to develop additional sources for stem cells as well as to apply cell therapy to more diseases and conditions. There is definitely immense room for further development, but stem cells have already had a significant impact on regenerative medicine and transplantation. In the future, diseases and conditions that are currently untreatable may be cured by stem cell therapy. They offer great promise for discoveries that may change the field of medicine.

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