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Stem Cells Overview-Mini-Review

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Abstract: Stem cells are unique and highly powerful cells, which have immense potential for treating various conditions. There are different types of stem cells based on the sources they are derived from and also based on their ability to differentiate into other types of cells. The detailed study of stem cells is important for scientists to understand how the cells grow and differentiate, and how the human body works on a cellular level. In addition to the research interest in stem cells, the clinical applications of stem cells are increasing constantly. Stem cells can be induced to change into new cells of specific tissues or organs, which can then be used for treating diseases. There are already a few established stem cell therapies, and many more in clinical trials.

Keywords: Stem cells, Current and potential uses, powerful cells.

1. Introduction

Stem cells represent a new frontier in medical technology, and have the potential to treat various diseases. The human body goes through a constant cycle of cell death and cell regeneration, and stem cells are the key players in the body's natural repair and regenerative mechanism. Stem cells are the self-renewing cells in our body, which repair damaged tissues and replenish dead cells. They can keep dividing and multiplying throughout a person's lifetime. Due to their unique properties, stem cells have become a major focus of scientific and clinical research studies. The sources, properties, structures, clinical details and potential uses of stem cells have been well researched over the past decade. Understanding how stem cells work is important to understand the entire process of cellular growth and differentiation in our body. Scientists now have enough information about these valuable cells to be able to use them for clinical applications. Stem cell therapy offers solutions to many medical conditions which have challenged scientists for decades.

There are some concerns about stem cell therapy, and these involve the ethical, safety and practical considerations in extracting and using stem cells. However, many of these concerns have been addressed by researchers in recent years, and stem cell therapy is fast becoming a feasible treatment option. This research aims to provide a detailed overview of stem cells and their clinical importance. In the following sections, we will take a closer look at stem cells, their properties and their potential use and concerns.

Stem cells: their unique properties and importance

Stem cells are unique because they are unspecialized and capable of differentiation (or changing) into other types of specialized cells in the body. So, stem cells from one particular lineage can change into stem cells of a different lineage and multiply. This unique property (called potency) allows scientists to use these powerful cells to grow different tissues and organs in the body.

However, not all stem cells can differentiate into a variety of other cell types. The most powerful stem cells are called totipotent stem cells which are present in the zygote, which then become nearly-as-powerful pluripotent stem cells in the embryo. These in turn can become any other type of cell in the body by applying suitable growth factors. The next most powerful stem cells are the multipotent ones, which are capable of changing into a few similar types of cells of a specific tissue or organ type. The least potent ones are the unipotent stem cells which can only self-renew and form one particular cell type. Figure 1 below shows the different levels of stem cells in terms of their ability to differentiate.

Let us look in detail at how stem cells differentiate into other specialized cells since this is their main and unique property. Within the human body, the stem cells in the embryo produce specialized cells for every tissue and organ type. The decisions of these stem cells to differentiate into other cell types depend on various physical and chemical signals from within the embryo. These signals cause gene activity which leads to the cell differentiation process.

In the laboratory, these signals are recreated by scientists to grow the cells in a dish. The main signaling molecules used to induce differentiation of the stem cells are growth factors which are added to the culture media. These growth factors can stimulate the cells to form only certain specialized cell types. Similarly, inhibitory growth factors can be added to prevent signals so that the stem cells do not differentiate into cells other than the desired cell type.

Different types of stem cells

Different types of human stem cells are derived from different sources in the body. In addition, stem cells can also be genetically modified to yield yet another type of stem cell. The major types of stem cells are embryonic stem cells, adult stem cells and induced pluripotent stem cells.

Embryonic stem cells are extracted from human embryos. Stem cells in the embryo are the most powerful ones which can grow into every type of cell and organ in the body (Brignier & Gewirtz, 2010). Through application of certain differentiation factors, researchers can grow entire organs out of a few stems' cells.

Adult stem cells are obtained from living human adults in a safe and non-destructive manner. All human adults have stem cells in different parts of their body for different purposes. These stem cells are present in adult tissues, organs, bone marrows and even blood. The fat tissues, bone marrows and blood of adult humans have the highest concentrations of stem cells. Adult stem cells are less powerful than embryonic stem cells because they are multipotent and can only differentiate into cells of similar tissue types. However, they are still very powerful in their ability to form new cells, and they can be used for many different disease models (Brignier & Gewirtz, 2010).

Induced pluripotent stem cells are lab grown and modified by scientists to combine the benefits of both embryonic and adult stem cells. Embryonic stem cells are pluripotent but challenging to extract, while adult stem cells are easy to obtain but lack the ability to differentiate into all cell types. So, scientists have developed pluripotent stem cells by genetic modification of multipotent adult stem cells. These are called induced pluripotent stem cells (iPSCs) and they share many similar characteristics with embryonic stem cells. These stem cells are originally derived from adult skin or blood cells. Then they are reprogrammed in the laboratory into becoming various other types of cell types as desired. Depending on the types of genes that are inserted into the cells, they can be induced to differentiate into liver cells, blood cells, neurons, beta islet cells and a few other cell types. Figure 2 below shows the process of preparing iPSCs from adult cells and using them to prepare various other types of cells.

Similarities and differences between the three types of stem cells

Embryonic stem cells, adult stem cells and iPSCs are all capable of self-renewing, multiplying and forming differentiating into other cell types. However, there are many differences between them. Embryonic stem cells (ESCs) and iPSCs are pluripotent, while adult stem cells are multipotent and less useful. ESCs are hard to obtain because they have to be drawn out from living human embryos, resulting in the death of embryos. This poses ethical concerns. But this is not an issue with adult stem cells or iPSCs, because they can be obtained from adult humans with their consent and without causing any injury or damage. These adult stem cells can then be further reprogrammed into iPSCs and grown in the laboratory. From a different aspect, once they are obtained, ESCs can be easily grown and multiplied in labs in culture dishes. However, adults stem cells must be obtained by extracting large amounts of tissues or blood from persons (because they are present in low concentrations), and then further processed and concentrated.

Another important difference between these stem cell types is that using ESCs in stem cell therapy can potentially cause immune rejection in the patient due to incompatibility between donors and recipients. With adult stem cells and iPSCs, the risk of rejection is reduced since the adult stem cells are usually extracted from the same patient. ESCs are of only one type (since they are pluripotent). However, there are different types of adult stem cells- depending on which tissue or cell type they were obtained from. The two well-studied types of adult stem cells are hematopoietic stem cells (HSCs) and mesenchymal stem cells (MSCs).

HSCs are present in the blood and bone marrow, and they are very useful for generating the components of blood- red and white blood cells, and platelets. They are already being used for treating leukemia (blood cancer). Figure 3 below shows how HSCs from the bone marrow can differentiate into various other related cell types.

MSCs are present in fat tissues and bone marrows, and can be used to generate many types of cells and tissues of similar lineage (Neirinckx et al., 2013). MSCs are unique because they do not get detected by the immune system. Thus, they are very promising for therapy as they can be transplanted from one patient to another without the risk of immune rejection. In the case of iPSCs, since they are reprogrammed and modified in the laboratory, they are much more versatile and easier to use than either ESCs or adult stem cells.

Current and potential uses of stem cells

There are many uses for stem cells, ranging from laboratory research, creating new cell types, studying how cells differentiate, and testing new treatments on them. The most exciting clinical use for stem cells is to replace damaged or diseased cells in the body, and to grow new tissues or organs using stem cells. Figure 4 below shows the many potential uses for stem cells that researchers are working on:

Adult stem cells such as MSCs and HSCs are already being clinically used to treat many conditions, including leukemia, arthritis, multiple sclerosis and cardiac problems. Stem cell therapies with MSCs are now being used for musculoskeletal regeneration (Steinert et al., 2012) and treating osteoarthritis (Davatchi et al., 2011). In addition, many other clinical trials are in progress using MSCs and other types of adult stem cells (Trounson et al., 2011)

Some of the conditions being evaluated in the stem cell clinical trials are diseases for which there is no existing successful treatment. For example, regeneration of diseased lung tissue has been considered impossible to date. However, a new type of stem cell has been discovered recently which shows the ability to regenerate lung tissues (Xian & McKeon, 2012). Stroke is yet another leading

cause of death and disability. In an exciting recent development, scientists have shown that dental pulp stem cells, a form of adult stem cells extracted from the molar, can improve both brain and limb functions following a stroke (Leong et al., 2012).

Obstacles and challenges facing development of stem cells

While the clinical and research developments indicate the immense potential of stem cells in curing many dangerous diseases, the risks and problems of stem cell therapies must also be considered. Using embryonic stem cells poses many ethical issues. Extracting these cells from the human embryo results in death of the embryo, so it is a sensitive matter to obtain embryonic stem cells. There are also concerns about these powerful stem cells being used for human cloning or other controversial uses. So, despite their usefulness, the extraction and use of embryonic stem cells is limited and tightly regulated.

Another point for concern is the ability of stem cells to rapidly self-renew and multiply. Even though they are present in our body, they have the ability to form unlimited number of cells, and can potentially lead to growth of unwanted tumors. Scientists report that the possibility of this occurrence is quite low (Prockop et al., 2010), yet stem cells need to be used with extreme care and expertise.

Another challenge in stem cell therapy is the practical considerations of large-scale preparation and usage. The process of extracting and processing the stem cells is not a simple step. This makes stem cell therapy very labor-intensive and expensive. It is currently difficult to make stem therapy widely available, and it is restricted to only limited patients and cases. However, there are rapid and ongoing advances in stem cell research, which may help overcome these challenges and make stem cell therapy more versatile and universal.

2. Conclusions

While there are ethical concerns in using ESCs, with the use of adult stem cells the ethical issue is no longer a constraint. The risks associated with stem cell therapy are relatively low since it involves non-invasive procedures. There is still much more progress to be made in this field, but stem cells are already set to change the future of medicine as we move towards more progressive, natural and regenerative treatment options for curing diseases.

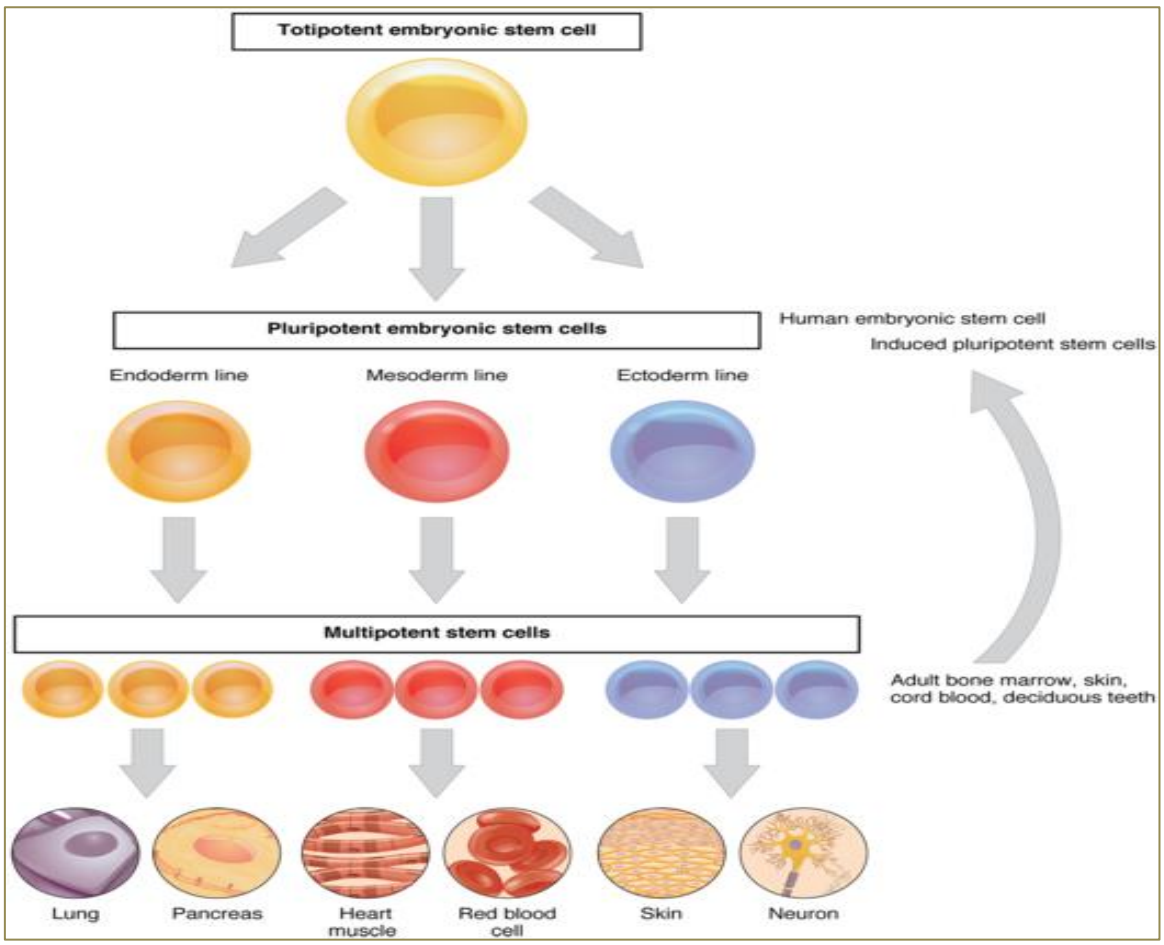

Figure 1. The stem cells hierarchy in terms of their potency

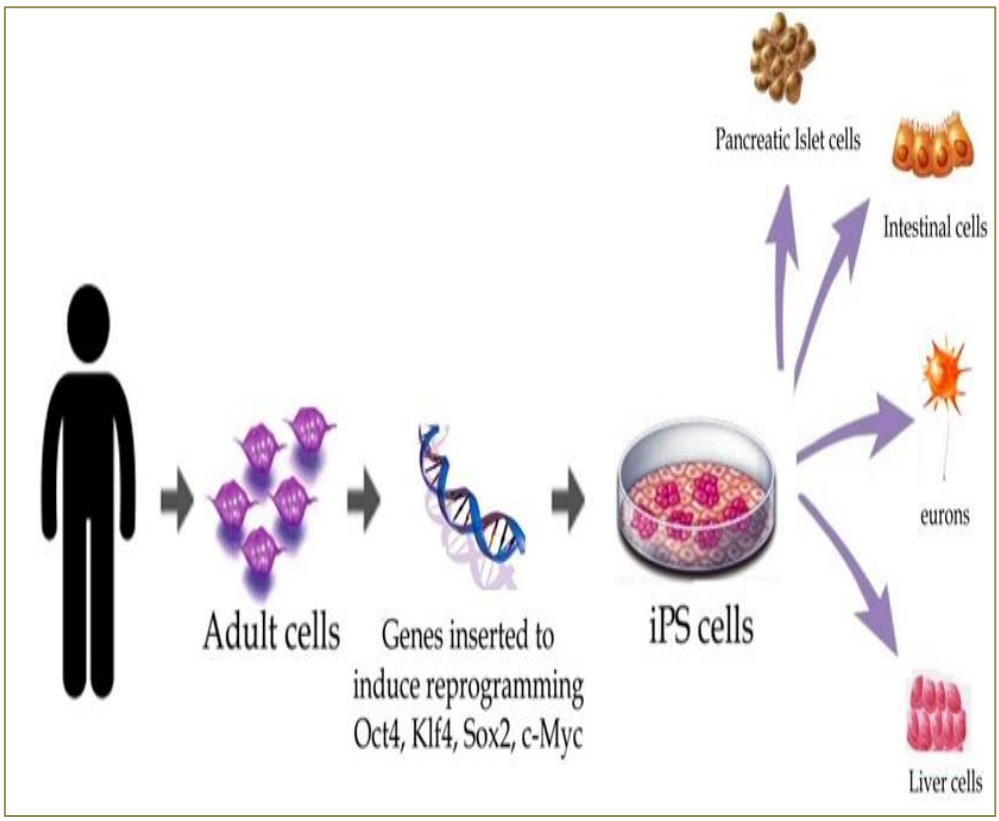

Figure 2. Developing induced pluripotent stem cells

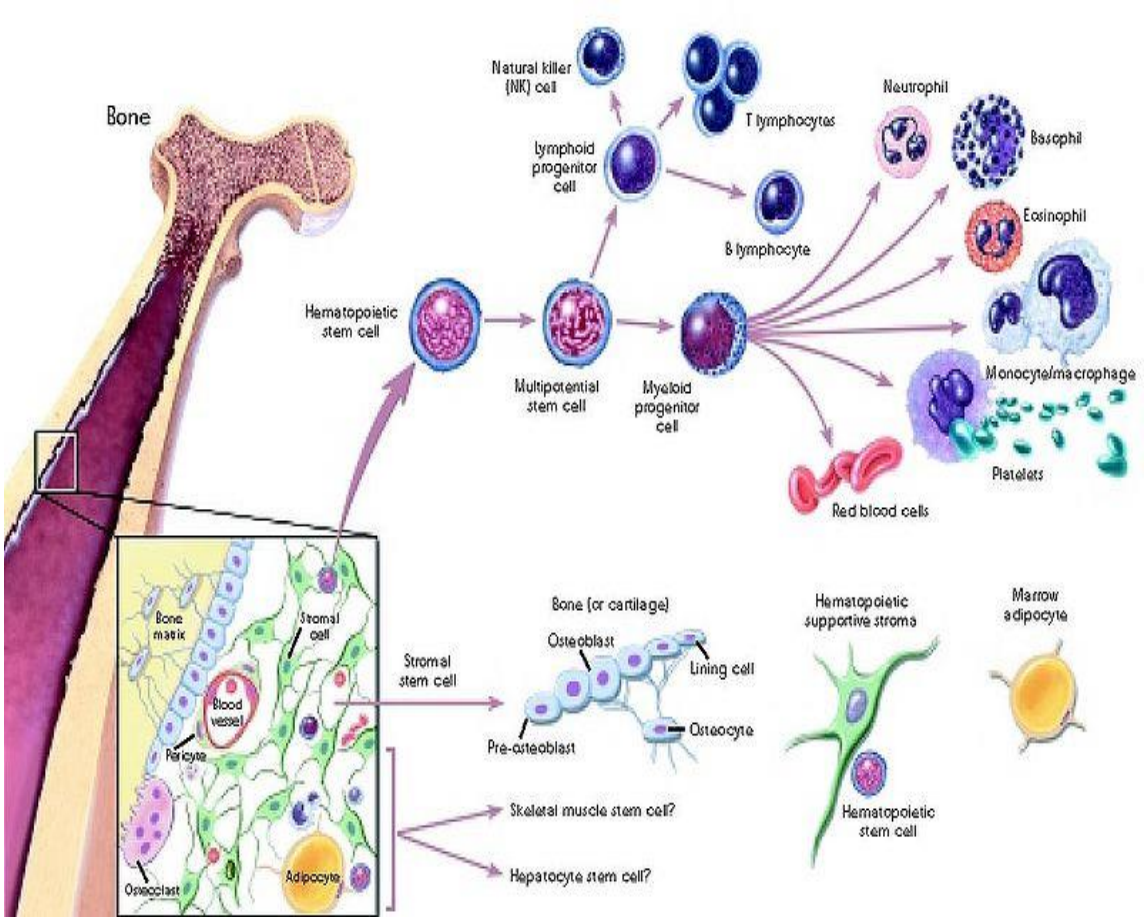

Figure 3. Differentiation of hematopoietic stem cells into other cells

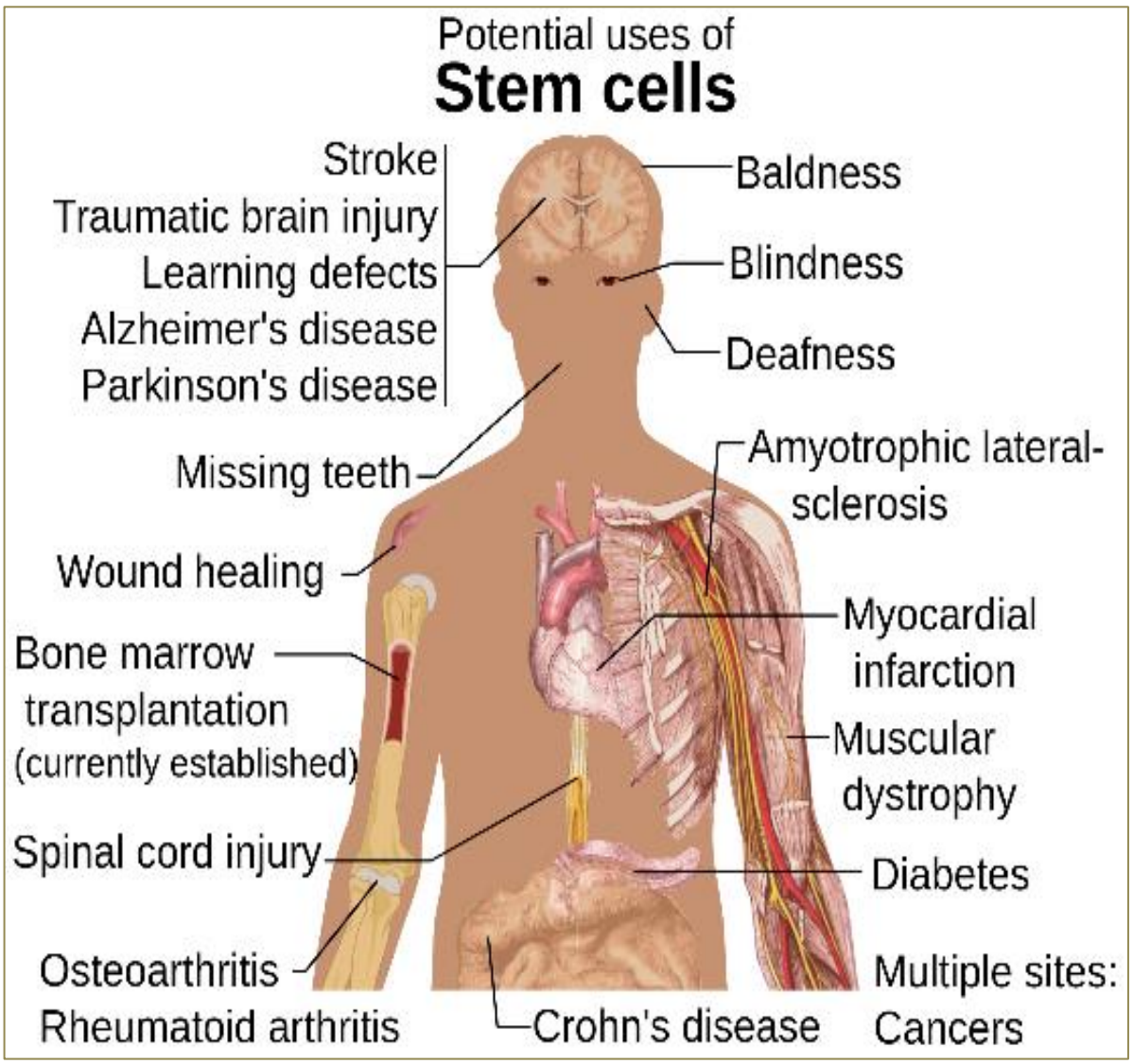

Figure 4. Potential uses of stem cells

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