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Stem Cell- A New Hope for Medical Science

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Abstract

Stem cells are cells that can multiply without changing, that is, self-renew, or can differentiate to produce specialized cell types. Stem cells has constituted a revolution in regenerative medicine and cancer therapies by providing the possibility of generating multiple therapeutically useful cell types. These new cells could be used for treating numerous genetic and degenerative disorders. However, human stem cell (hSC) research also raises sharp ethical and political controversies. The ethical and policy issues need to be discussed along with scientific challenges to ensure that stem cell research is carried out in an ethically appropriate manner. The issue of stem cell research is politically charged, prompting biologists to begin engaging in ethical debates, and generating in the general public an unusually high level of interest in this aspect of biology. To bring stem cell technology into clinical practice for regenerative medicine, a thorough understanding of the basic principles underlying stem cell regeneration and regulation of self-renewal versus differentiation is absolutely essential.

Keywords: Stem cells; Applications; Prospects; Ethical

Introduction

Since the discovery in the early 1900s, stem cells have captured the imagination of the scientists. Interests intensified, however, in 1998, when Professor James Thomson at the University of Wisconsin isolated and grew germ stem cells derived from human embryos [1]. Soon thereafter, researchers from Johns Hopkins University achieved similar results with human germ cells [2]. These advances impelled a wave of stem cell research around the world, focusing on three areas: human development, birth defects and therapeutics.

What is Stem Cell

Stem cell are unspecialized with remarkable potentiality to develop into many different cell types .They are capable of renewing themselves through cell division. Under special condition they can be induced to become tissue or specific cell with defined function, these distinguishing features make stem cell different from other types of cell. Stem Cells are undifferentiated cells that through replication have the capability of both self-renewal and differentiation into mature specialized cells [3].

Properties of Stem Cell

Stem cells have some unique properties compared to normal cells. First, they have longevity. They divide and replicate under laboratory conditions for long periods of time without differentiating until induced to do so. Second, they have plasticity. They are able to differentiate into different types of specialized cells, such as cardiac muscle or pancreatic cells [4].

Types of Stem Cells

There are essentially two kinds of stem cells-embryonic and adult. Embryonic stem cells (ESCs) are harvested from the very early blastocyst stage of a human fertilized egg and are described as totipotent (able to develop into any body cell type, including placental tissue). Adult stem cells are found in developed tissue, such as bone marrow cells. They can be pluripotent (able to give rise to any type of cell in the body except those needed to develop a fetus) or multipotent (able to give rise to a small number of specific cell types, such as bone or muscle tissue). Hematopoietic stem cells- blood stem cells that can develop into several types of blood cells but no other types of cells- are one kind of mutipotent stem cells [5].

Advantages of Stem Cells

Human embryonic and adult stem cells each have advantages and disadvantages regarding potential use for cell-based regenerative therapies. Of course, adult and embryonic stem cells differ in the number and type of differentiated cells types they can become. Embryonic stem cells can become all cell types of the body because they are pluripotent. Adult stem cells are generally limited to differentiating into different cell types of their tissue of origin. However, some evidence suggests that adult stem cell plasticity may exist, increasing the number of cell types a given adult stem cell can become. Large numbers of embryonic stem cells can be relatively easily grown in culture, while adult stem cells are rare in mature tissues and methods for expanding their numbers in cell culture have not yet been worked out. This is an important distinction, as large numbers of cells are needed for stem cell replacement therapies [5].

A potential advantage of using stem cells from an adult is that the patient's own cells could be expanded in culture and then reintroduced into the patient. The use of the patient's own adult stem cells would mean that the cells would not be rejected by the immune system. This represents a significant advantage as immune rejection is a difficult problem that can only be circumvented with immunosuppressive drugs. Embryonic stem cells from a donor introduced into a patient could cause transplant rejection. However, whether the recipient

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would reject donor embryonic stem cells has not been determined in human experiments [6].

Sources of Stem Cells

The most ready source of embryonic stem cells for research and therapeutic use is early-stage embryos created in vitro (through nuclear transfer), with the embryos then harvested at the blastocyst phase. Controversy exists regarding the use of this source of embryonic stem cells. A less controversial source of embryonic stem cells, though one also not completely free from controversy, is embryos produced for the in vitro fertilization process [7]. The most common sources of adult stem cells are blood, bone marrow and adipose tissue. Stem cells normally circulate in the blood in very small quantities and can be collected from the blood through a small catheter inserted into a patients' vein. Blood cell growth factors called cytokines can be administered to patients to produce a substantial increase in the number of circulating blood stem cells for collection. This process is referred to as stem cell mobilization. The collection of stem cells from bone marrow has been safely performed since the 1970s [8]. Adipose or fat tissue is an exciting source of adult stem cells due to the high number of stem cells it contains. Fat tissue containing stem cells can be extracted from the body through liposuction. Some stem cells derived from fat tissue have been found to have multipotent activity [9] and have been reprogrammed into other cell types, including muscle, cartilage and bone cells [2,10].

Potential Therapeutic Applications

One of the most fascinating medical applications of stem cell research is in integrative medicine, which uses stem cells to generate tissue that can repair failing organs. With the potential to change medical practice in both treating and cuing disease, the application of regenerative medicine span a wide array of debilitating diseases [11]. The following paragraphs describe a few of these promising applications, including heart disease, diabetes and neurological disorders.

Heart disease

Stem cell technology provides hope for the cure of heart disease. For example- in congestive heart failure, heart muscle is damaged and functional tissue is replaced with nonfunctional scar tissue, reducing the ability of the heart muscle to contract. Geron Corporation, USA has generated functioning human cardiomyocytes (heart muscle cells) in culture from embryonic stem cells that can potentially replace the scar tissue [12].

Insulin dependent diabetes mellitus

Another potential therapeutic application of stem cells is in the treatment of insulin-dependent diabetes mellitus. The daily insulin injections have profound effects on the patient's quality of life. Embryonic stem cells induced in vitro to become insulin-secreting cells and transferred to diabetic animals have restored normal glucose balance within a week [13].

Neurological disorders

Perhaps the most astounding application of stem cells is in the treatment and cure of neurological disorders. Researchers recently transplanted embryonic stem cells in to the brains of mice and found that the stem cells differentiated into dopaminergic neurons, restoring partial (80%) neural function in the rat and mouse model of Parkinson's disease [14,15]. Similarly promising results have been observed in rats with spinal cord injuries [16].

Stem cells can be used to study development

Stem cells may help us understand how a complex organism develops from a fertilised egg. In the laboratory, scientists can follow stem cells as they divide and become increasingly specialized, making skin, bone, brain, and other cell types. Identifying the signals and mechanisms that determine whether a stem cell chooses to carry on replicating itself or differentiate into a specialized cell type, and into which cell type, will help us understand what controls normal development [17,18].

Stem cells have the ability to replace damaged cells and treat disease

This property is already used in the treatment of extensive burns, and to restore the blood system in patients with leukaemia and other blood disorders. Stem cells may also hold the key to replacing cells lost in many other devastating diseases for which there are currently no sustainable cures. Today, donated tissues and organs are often used to replace damaged tissue, but the need for transplantable tissues and organs far outweighs the available supply. Stem cells, if they can be directed to differentiate into specific cell types, offer the possibility of a renewable source of replacement cells and tissues to treat diseases including Parkinson's, stroke, heart disease and diabetes. This prospect is an exciting one, but significant technical hurdles remain that will only be overcome through years of intensive research [19].

Stem cells could be used to study disease

In many cases it is difficult to obtain the cells that are damaged in a disease, and to study them in detail. Stem cells, either carrying the disease gene or engineered to contain disease genes, offer a viable alternative. Scientists could use stem cells to model disease processes in the laboratory, and better understand what goes wrong [20].

Stem cells could provide a resource for testing new medical treatments

New medications could be tested for safety on specialized cells generated in large numbers from stem cell lines – reducing the need for animal testing. Other kinds of cell lines are already used in this way. Cancer cell lines, for example, are used to screen potential anti-tumour drugs [21].

Recent Advances in Stem Cell Research

Some recent developments have the potential to radically alter the direction of research in the development of stem cell therapies. Proceedings of the National Academy of Science [22] reported that stem cells from bone marrow transplant migrated from bone to brain. The implications are that stem cell therapies do not need to be administered locally and they could be relatively easily delivered because they will migrate to the "correct" target [23].

Catherine Verfaillie and her colleagues at the University of Minnesota [24] found that adult stem cells derived from bone marrow were capable of differentiating into every type of human tissue, eliminating the possibility of immune rejection- a property previously believed to be characteristics of embryonic stem cells. An implication of this research is that therapeutic cloning would no longer be necessary.

Future Developments

Improvements in harvesting techniques and growth of stem cells in the laboratory will lead to increased safety of autografts and an expanding list of indications. Purging of stem cell transplants may become routine to reduce contamination with tumour cells. Reductions in the intensity of conditioning regimens for allografts will improve safety and increase applicability. Such transplants may be followed by higher relapse rates, but these will be offset by use of graft versus tumour effects by infusion of donor lymphocytes. Ongoing research programmes with potential clinical applications include development of vehicles for gene therapy, tumour specific vaccines, and radionuclide conditioning agents [25,26].

Although the significant advancements in stem cell research have provided important information on stem cell biology and offer great promise for developing novel successful stem cell-based medical treatments, further investigations appear to be necessary to translate the basic knowledge into clinical therapeutic applications in humans. Additional studies to optimize the experimental conditions for isolation, expansion, and differentiation of human stem/progenitor cells into specific differentiated cells in vitro, ex vivo, and in vivo, and more particularly for human ESCs, are essential before their possible use in treating human pathological disorders [27,28]. The identification of specific biomarkers to each type of adult stem/progenitor cells relative to their more committed and mature progeny is important for the characterization of their specific physiological functions. The determination of temporal changes in extrinsic factors and specialized niches of adult stem cells may notably provide information on the sequence of molecular events that may be associated with each stage of development of a particular disease in humans [29,30].

Challenges of Stem Cell Research

Adult stem cells have been used therapeutically for years in the form of bone marrow transplants. Nevertheless, many technical challenges must still be overcome before stem cells can be used to treat a wide range of disorders. Examples are highlighted below.

Supply

Stem cells can be taken from a variety of sources, including an embryo, a patient, a patient's relative, or an established stem cell line. Each source presents unique challenges. Established cell lines may seem like the obvious choice, but some scientists are concerned that these cells have built up a lot of mutations as they have undergone thousands of divisions.

Transplantation into the target area

The delivery of stem cells to targeted tissues can be complex, especially if the tissues are deep inside the body. And once delivered, stem cells must "learn" to work with other cells. For instance, inserted cardiac cells must beat in unison with a patient's heart cells to be effective.

Prevention of rejection

Stem cells may be rejected if a patient's body sees them as foreign. This problem can remain even when certain identifying proteins are removed from the cells' membranes. The development of SCNT technology in humans could help solve this problem so that patients would not have to take drugs to suppress their immune system [31].

Suppression of tumor formation

By their very nature, stem cells remain undifferentiated and continue to divide for long periods of time. When transplanted into an organism, many embryonic stem cells tend to form tumors. This risk must be removed before they can be used therapeutically [32].

To summarize, the promise of stem cell therapies is an exciting one, but significant technical hurdles remain that will only be overcome through years of intensive research.

Ethical Issue of Stem Cell Research

Ethical challenges are not new to medicine and medical research. Stem cell research raises the concern that humans are "playing god". This concern is particularly relevant when discussing the cloning of human embryos for research purposes. There is also the possibility of inadvertent germ-line (reproductive cells) manipulation, even with the use of adult stem cells [33]. Germ-line manipulation would result in the genetic modification of the offspring and would have a permanent impact on the human species [34,35].

As therapies are developed and commercialized, society will have to consider the ethical implications of not only science but also the management of the corporations that bring such treatments to market [36,37].

The source of tissues used to obtain stem cells in one of the most incendiary topics surrounding stem cell research. The president's council of Bioethics suggested three primary and recurring points of contention with regard to the issue of tissue sources: the moral status of human embryos, complicity and the "alternative of adult stem cells" [38,39].

Stem cell research is controversial not because of its goals, but rather because of the means of obtaining some of the cells. The crux of the debate centers around embryonic stem cells, which enable research that may facilitate the development of medical treatments and cures, but which require the destruction of an embryo to derive. In addition, because cloning is one method of producing embryos for research, the ethical issues surrounding cloning are also relevant [40] (Table 1).

Conclusion

Stem cell research has the potential to lead to the development of novel cellular and gene therapies that could be translated into effective and safe clinical treatments of numerous genetic and degenerative disorders in humans. Although stem cells are highly unlikely to contribute to human fantasies of immortality and eternal youth, tremendous progress has been made in the past few years in the potential use of these cells as therapeutic agents, which may lead to prolonged life with less suffering and higher quality. In order to safely use stem cells or their differentiated progeny, methods of purification and methods of cell-death control will need to be developed. Another important aspect of stem-cell-based therapies will be the necessity of

Phase of research	Ethical issues
Donation of biological materials	Informed and voluntary consent
Research with hESCs	Destruction of embryos Creation of embryos specifically for research purposes 1. Payment Sto oocyte donors 2. Medical risks of oocyte retrieval 3. Protecting reproductive interests of women in infertility treatment
Use of stem cell lines derived at another institution	Conflicting legal and ethical standards
Stem cell clinical trials	Risks and benefits of experimental intervention Informed consent

Table 1: Ethical issues at different phases of stem cell research.

preventing the rejection of the donated cells by the immune system. In summary, much basic research lies ahead before application of a stem cell therapy to patients in a rigorous therapeutic manner is realized. However, mankind will surely benefit enormously by conducting research in this important area.

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