GSC Biological and Pharmaceutical Sciences
eISSN: 2581-3250 CODEN (USA): GBPSC2
Cross Ref DOI: 10.30574/gscbps
Journal homepage: https://gsconlinepress.com/journals/gscbps/

(REVIEW ARTICLE)

Check for updates

A review on stem cells and its therapies

Nagesh G. Khansole *, Supriya S. Barewar, Ravindra L. Bakal, Pooja R. Hatwar, Umesh S. Saware and Niranjan D. Waghmare

Department of Pharmacology, Shri Swami Institute of Pharmacy, At Parsodi, Dhamangaon Rly, Dist-Amravati (444709) Maharashtra, India.

GSC Biological and Pharmaceutical Sciences, 2025, 31(03), 094-105

Publication history: Received on 18 April 2025; revised on 03 June 2025; accepted on 06 June 2025

Article DOI: https://doi.org/10.30574/gscbps.2025.31.3.0208

Abstract

Stem cells are undifferentiated cells that can self-renew and differentiate into specialized cell types, holding immense potential for regenerative medicine. These cells can be classified into embryonic and adult stem cells, each with unique properties and applications. Potential stem cells are classified into five kinds based on differentiation: totipotent, pluripotent, multipotent, oligopotent, and unipotent. Our brains, bones, muscles, nerves, blood, skin, and other organs depend on them for growth, development, maintenance, and repair. With numerous health advantages. Embryonic stem cells are pluripotent, capable of differentiating into any cell type, while adult stem cells are multipotent, with limited differentiation potential. Stem cells have been explored for treating various diseases, including diabetes, liver disease, muscular dystrophy, and cardiovascular disorders. Stem cell-based therapies have shown promise in preclinical and clinical trials, offering potential treatments for currently incurable conditions. However, challenges persist, including ensuring safety, efficacy, and scalability. Further research is needed to overcome these hurdles and fully harness the therapeutic potential of stem cells.

Keywords: Stem Cells; Regenerative Medicine; Cell Biology; Adult Stem Cells; Stem Cell Therapy

1. Introduction

Stem cells are a rare and adaptable cell type that can reproduce endlessly, rejuvenate themselves, and produce specialized cell types. Stem cells are uncommitted and stay uncommitted until they get a signal to develop into specialized cells, in contrast to most body cells, such as skin or heart cells, which are committed to performing a certain role. Stem cells are unusual because of their propensity for proliferation and specialization [1]. Cells that can develop into several cell lineages and have the ability to clone and self-renew are known as stem cells. From the earliest phases of human development until the end of life, stem cells are present in every individual. The unspecialized cells known as stem cells give rise to the specialized cells that comprise the many tissue types seen in the human body. Their capacity to self-renew via mitotic cell division and differentiation into a wide variety of specialized cell types is what distinguishes them [2]. Even the most technologically advanced nations are plagued by morbidity and mortality due to failures in essential organs. There is increasing optimism that stem cells could be the solution to humanity's longing to replace tissues damaged by illness and aging due to the scarcity of transplantable organs [3].

1.1. What is Stem Cell?

A stem cell is one that can divide (self-replicate) indefinitely, frequently throughout the duration of an organism's life. Stem cells have the capacity to differentiate into mature cells with distinctive forms and specific roles, such as heart, skin, or nerve cells, provided the proper circumstances or cues are given [1].

* Corresponding author: Nagesh G. Khansole.

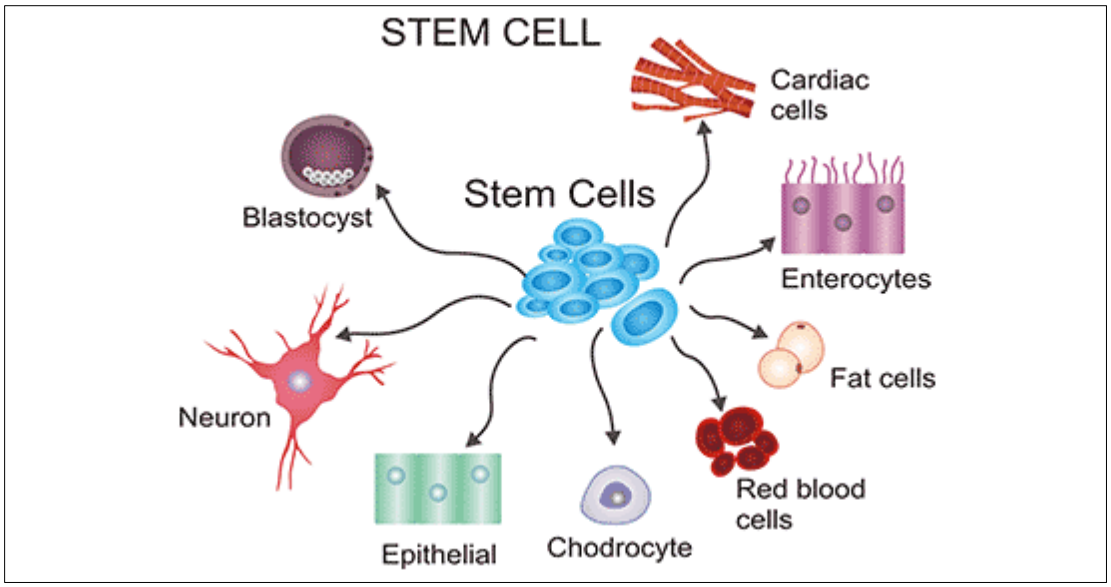

Figure 1 Showing stem cell [1]

2. Stem cell Biology

Following the merging of sperm and ovum fertilization, a blastocyst is created. Short-lived stem cells, specifically embryonic stem cells, line its inner wall. The two different cell types that make up blastocysts are the trophectoderm (TE) and the inner cell mass (ICM), which differentiates into epiblasts and stimulates fetal development. ICM microenvironment control is the responsibility of blastocysts. The placenta and other extraembryonic support structures required for the embryo's successful origin are formed by the TE as it develops further. The ICM cells continue to be undifferentiated, totally pluripotent, and proliferative as the TE starts to develop a specific support structure [4]. Because stem cells are pluripotent, they can differentiate into any type of cell in the body. The ICM is where human embryonic stem cells originate. Each of the three germ layers endoderm, mesoderm, and ectoderm that are formed by cell aggregations during embryogenesis eventually gives rise to differentiated cells and tissues of the fetus and, subsequently, the adult organism (Fig. 2). hESCs become multipotent stem cells, whose potency is restricted to germ layer cells, after differentiating into one of the germ layers. In terms of human growth, this procedure is brief. Following that, pluripotent stem cells are found throughout the body as undifferentiated cells. Their primary functions include proliferating by generating more stem cells and differentiating into specialized cells under certain physiological conditions [5].

There are two types of signals that affect the stem cell specialization process: internal signals, which are regulated by genes in DNA, and external signals, which include physical contact between cells or chemical secretion by surrounding tissue. Stem cells also operate as internal repair systems of the body. If an organism is alive, its cell production and replenishment are limitless. The organ in which stem cells are found determines their activity; for example, in bone marrow, they divide continuously, while in organs like the pancreas, this only happens under specific physiological circumstances [6].

2.1. Stem cell functional division

The existence of distinct stem cells during division depends on how the organism develops. ESCs (somatic stem cells) can be identified. While it is feasible to derive ESCs without separating from the TE, this combination has growth limitations. Co-culture of these is typically prevented because to the limited number of proliferating actions [7].

The inner cell mass of the blastocyst, a stage of the pre-implantation embryo that occurs about four days after fertilization, is the source of ESCs. These cells are then put in a culture dish that has been loaded with culture media. Passage is a common yet ineffective method of subculturing cells on different dishes. Since these cells can eventually differentiate into any form of cell in the body, they are referred to as pluripotent cells. The medicinal application of ESCs in treatments has been subject to ethical limitations since the start of their research. The majority of embryonic stem cells are produced from in vitro fertilized eggs rather than in vivo fertilized eggs [8].

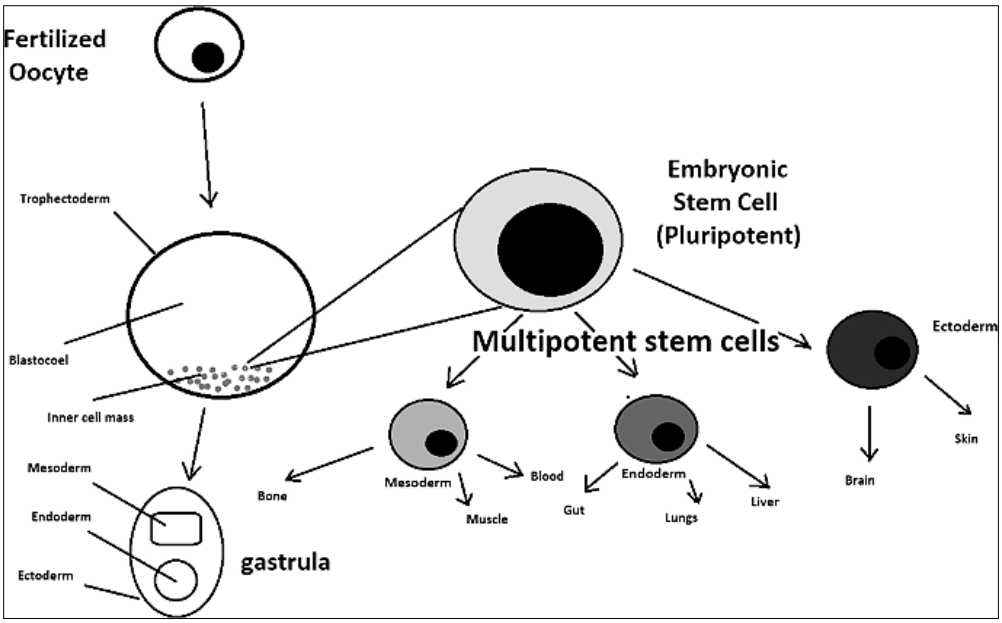

Figure 2 Oocyte development and formation of stem cells: the blastocoel, which is formed from oocytes, consists of embryonic stem cells that later differentiate into mesodermal, ectodermal, or endodermal cells. Blastocoel develops into the gastrula [4]

After development, differentiated cells throughout the body contain somatic or adult stem cells, which are undifferentiated. These cells serve to facilitate the growth, repair, and replacement of cells that are lost on a daily basis. These cells can only differentiate in a limited number of ways.

There are numerous varieties, including the following

- Numerous tissues include mesenchymal stem cells. These cells primarily develop into bone, cartilage, and fat cells in bone marrow. Since they can specialize in any germ layer's cells and behave as pluripotent stem cells, they are an exception.
- Nerve cells and the oligodendrocytes and astrocytes that support them are produced by neural cells.
- Red, white, and platelet blood cells are all produced by hematopoietic stem cells.
- Keratinocytes, which create the skin's protective layer, are one type of skin stem cell [7,9].

3. Types of Stem Cells

They are separated into two categories: nonembryonic (sometimes referred to as adult stem cells) and embryonic. Potential stem cells are classified into five kinds based on differentiation: totipotent, pluripotent, multipotent, oligopotent, and unipotent. Both embryonic and extraembryonic cell types can be differentiated from totipotent stem cells. Multipotent stem cells differentiate into any cell type of a primarily closely related cell family, while pluripotent stem cells give birth to any kind of endoderm, mesoderm, or ectoderm. The differentiation potential of oligopotent and unipotent stem cells is limited to a single cell type and a limited number of cell types, respectively [10].

3.1. Totipotent

Totipotent stem cells have the ability to proliferate and differentiate into all of the body's cells. The ability of cells to differentiate into both embryonic and extra-embryonic tissues is known as totipotency. A zygote, created when a sperm fertilizes an egg, is an example of a totipotent cell. These cells have the potential to grow into a placenta or any one of the three germ layers. The inner cell mass of the blastocyst becomes pluripotent after around 4 days. The source of pluripotent cells is this structure [2].

3.2. Pluripotent

The capacity to differentiate into nearly any sort of cell. The mesoderm, endoderm, and ectoderm germ layers that emerge during the early phases of embryonic stem cell differentiation are examples, as are cells produced from embryonic stem cells [2]. One of the initial problems with using iPSCs was the poor experimental efficiency in the

successful induction of pluripotency to somatic cells. The use of genetic factors, chemical inhibitors, and signalling molecules that can either replace core reprogramming factors or enhance re programming efficiency has now been investigated [11].

3.3. Multipotent

The capacity to develop into a closely related cell family. Hematopoietic (adult) stem cells, which can develop into platelets or red and white blood cells, are one example. Although multipotent stem cells can specialize in distinct cells of particular cell lineages, their range of differentiation is more limited than that of PSCs. A hematopoietic stem cell, which may differentiate into many blood cell types, is one example [4].

3.4. Oligopotent

The capacity to develop into a small number of cells. Adult myeloid or lymphoid stem cells are two examples. Numerous cell types can be differentiated from oligopotent stem cells. One type of stem cell that can differentiate into white blood cells but not red blood cells is a myeloid stem cell [4].

3.5. Unipotent

The capacity to only generate cells of their own kind while possessing the self-renewal quality necessary to be classified as a stem cell. Adult muscle stem cells are one example. The limited capacity for differentiation and the unique ability to divide repeatedly are characteristics of unipotent stem cells. They are a viable option for therapeutic application in regenerative medicine because of their latter characteristic. These cells can exclusively differentiate into one type of cell, such as dermatocytes [2].

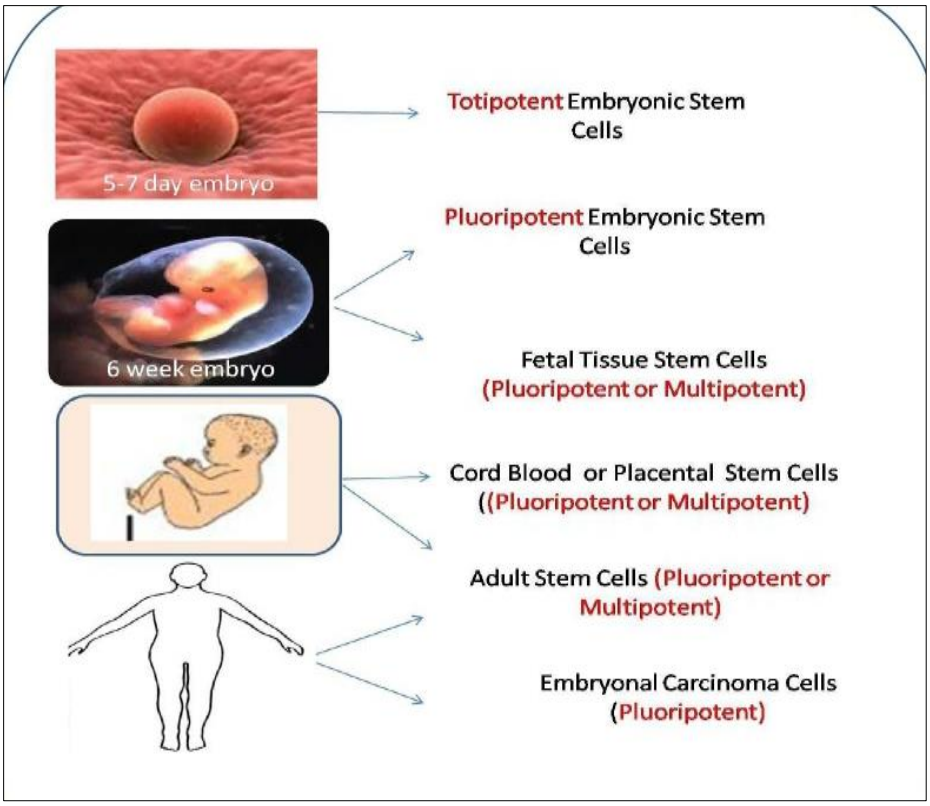

Figure 3 Classification of stem cell on basis of potency [5]

Numerous fundamental and clinical investigations have been conducted on stem cells since their concept was published, and they are considered to be potential therapeutic agents due to their special abilities to differentiate and self-renew. Since tissue regeneration and cellular replacement are at the forefront of regenerative medicine, several stem cell types including progenitor cells, multipotent stem cells, and human pluripotent stem cells (hPSCs) have been employed to accomplish these goals [12]. The first bone marrow transplant was performed in 1956, marking the beginning of stem cells' use in contemporary regenerative medicine in the 1950s. This discovery cleared the path for the currently

available stem cell therapies and provided insight into the possible treatments that could be developed in the future with additional clinical technique development and improvement [6].

With an emphasis on the application of stem cells in dentistry as well as the advancements made in regenerative therapy modalities for a number of disorders, this study describes the progress and obstacles facing the development of stem-cell-based therapies. While illuminating the ethical and legal difficulties in converting autologous stem cell-based interventions into safe and efficient therapies, the limitations of these treatments and current difficulties in the area are also covered [7]. The first step in implementing a new treatment approach is to comprehend the detailed knowledge that underlies the conversion of concepts into medical services [13].

4. Uses of stem cells

Stem cell transplant is an exciting area of medicine. It is a well-established treatment for several cancers and diseases of blood, for the past few decades [14].

4.1. Diabetes (Type 1 and 2)

Because researchers have already demonstrated that mesenchymal stem cells can develop into pancreatic beta-islet cells following in vitro culture, stem cell therapy is the most effective treatment for diabetes mellitus. Treatment with autologous bone marrow-derived mesenchymal stem cells (MSCs) has immune-regulatory properties and halts the immune attack by secreting anti-inflammatory cytokines (IL-10, TGF-beta, and IL-1). Diabetes is an autoimmune and metabolic disease, meaning that our body attacks our own pancreatic cells as foreign cells. Patients with diabetes respond well to stem cell therapy because bone marrow-derived stem cell concentrate (CD44+, CD31+, and CD34+) can regenerate beta islet cells [15].

4.2. Acute/Chronic liver disease

Numerous clinical studies have demonstrated the effectiveness of stem cell therapy in treating liver-related conditions such as end-stage liver disease (ESLDs) and acute liver failure. The idea is that stem cells can develop into hepatocyte cells following liver disease transplantation and exhibit improvement across the board in liver-related evaluations [16].

4.3. Muscular dystrophy

Although there is no known cure for muscular dystrophy, mesenchymal stem cell (MSC) therapy primarily targets the inflammatory response in this condition. Mesenchymal stem cells are superior to other cell-based treatments for DMD when it comes to treating muscular dystrophy [17].

5. Sources of Stem Cells

Stem cells come from a variety of origins. It is possible to separate pluripotent stem cells from human embryos as early as a few days. Pluripotent stem cell "lines" cell cultures that can be continuously cultivated in a lab—may be made from the cells of these embryos. Additionally, pluripotent stem cell lines derived from lethal tissue (tissue older than 8 weeks of development) have been created. Adult stem cells and embryonic stem cells are the two main types of stem cells that are present in humans [9].

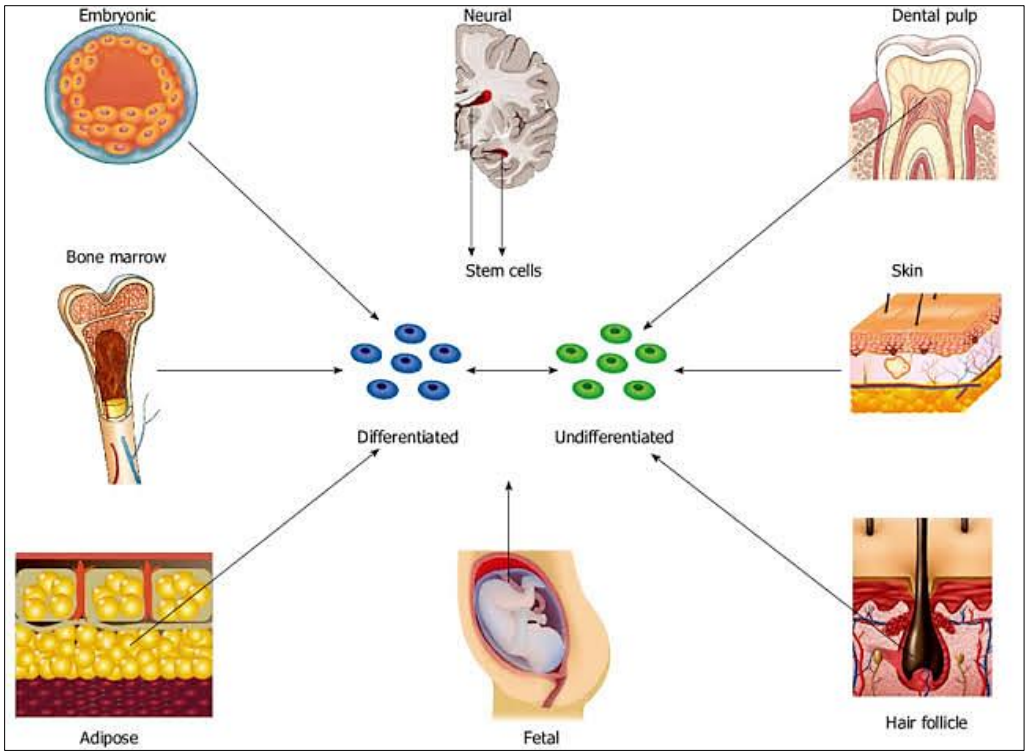

Figure 4 Various sources of stem cells [9]

5.1. Embryonic stem cells

One unique feature of embryonic stem cells is that they are the source of all other cell types in the human body. The blastocyst, the earliest stage of human embryo development, forms about four days after conception and gives rise to these cells. The blastocyst is made up of two separate parts: an exterior layer of cells and an inner mass of cells that come together to create a hollow ball. Pluripotent cells that can differentiate into stem cells and then produce cells with specialized functions are found within the inner cell mass [18].

5.2. Adult stem cells

The majority of adult tissues, including bone marrow and fat, contain trace amounts of these stem cells. Adult stem cells are less able to differentiate into different bodily cells than embryonic stem cells. Until recently, scientists believed that adult stem cells could only produce cells that were comparable to one another. For example, scientists believed that bone marrow-resident stem cells could only produce blood cells [19].

- Cord blood, umbilical cord blood
- Bone marrow
- Blood, peripheral blood stem cells
- Menstrual blood
- Skin
- Teeth
- Placental tissue

These adult stem cell sources all have certain traits in common. Others are distinct, and new choices are being investigated every day [12].

5.3. Amniotic stem cells

Amniotic fluid also contains multipotent stem cells. These are highly active stem cells. They are not carcinogenic and spread widely in the absence of feeders. Multipotent amniotic stem cells can differentiate into endothelial, hepatic, myogenic, adipogenic, osteogenic, and neuronal cell types [20].

5.4. Foetal stem cells

Foetal stem cells are the basic stem cells found in the organs of foetuses. Foetal stem cells come in two varieties:

- The tissue of the foetus proper is where fatal appropriate stem cells originate. Following an abortion, they are acquired. Although these stem cells are multipotent and have a high rate of division, they are not immortal [21].
- Extra embryonic membranes give rise to extra embryonic fatal stem cells. Adult stem cells are not differentiated from them. After birth, these stem cells are acquired. Despite their rapid rate of cell proliferation and pluripotency, they are not immortal [15].

5.5. Bone Marrow Stem Cells

Different cell types with distinct behaviors and functions make up bone marrow. Both whole, unfractionated bone marrow and a specific subset of bone marrow cells can be transplanted. Due to its easy accessibility, autologous origin, and capacity to transdifferentiate into either vascular or cardiac cells, bone marrow has lately drawn interest as a possible source of multipotent stem cells treating cell cardiomyopathy [22].

The iliac crest is often aspirated to extract total unfractionated bone marrow, which is then promptly injected into the injured myocardium. This method is ineffective even if it appears to be very easy, practical, and direct. Research on sheep revealed that injecting unfractionated bone marrow into scar tissue1 did not improve regional or global cardiac function and injecting it into the myocardium did not improve hemodynamics. Grafted cells did not transdifferentiate into either vascular cells or car Dio myocytes, according to histologic examination. The fact that there are so few multipotent cells in total bone marrow that may transdifferentiate into cardiomyocytes per unit of volume may help to explain these findings. Thus, the effectiveness of employing entire unfractionated bone marrow is still up for debate [23].

5.6. Expansion of stem cells

Expanding the number of available SCs is a crucial first step toward better SC therapy. It would be advantageous to have more cells available for treatment because the homing of cells to injured tissues is incredibly inefficient. To boost the number of cells, autologous BM cells, adipose tissue, myocardium, and UCB are cultivated ex vivo. Selecting particular cells is another benefit of tissue culture. Before a preparation can be expanded, extra processes are needed for ESCs and iPS cells. The first stage for iPS cells is dedifferentiation; after that, both iPS cells and ESCs are stimulated to differentiate before they can proliferate. Colonies are formed by SCs in culture, and their proliferation without differentiation need a particular order and timing of growth factor and cytokine availability [24].

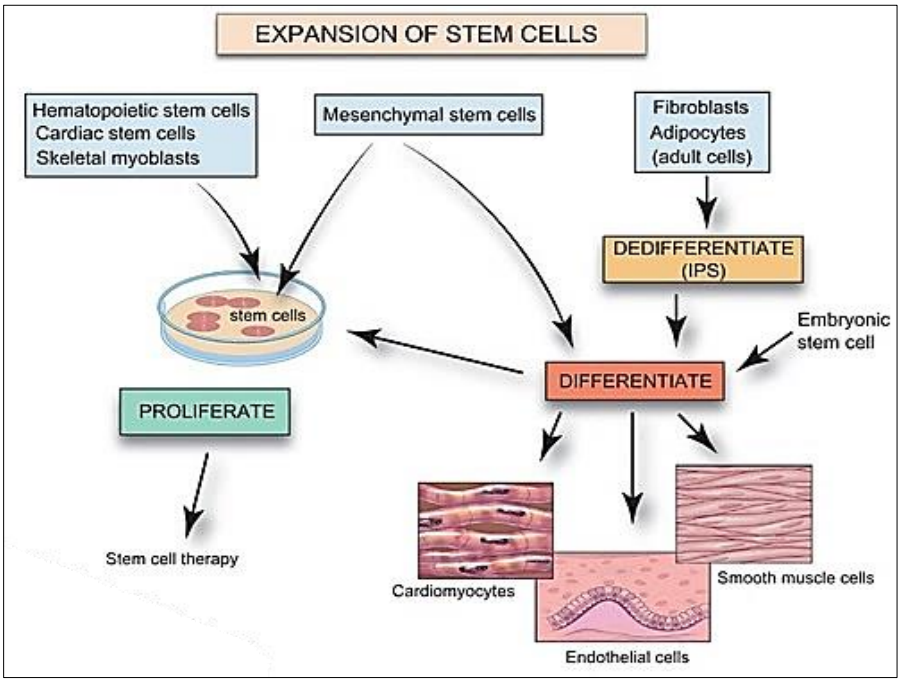

Figure 5 Expansion of stem cells [24]

6. Possible Treatments by Stem Cells

With the notable exception of bone marrow transplantation, the majority of stem cell therapies are either expensive or still in the experimental stage. Researchers in medicine believe that adult and embryonic stem cells will soon be used to treat a wide range of conditions, including cancer, Type 1 diabetes, Parkinson's disease, Huntington's disease, celiac disease, heart failure, neurological problems, muscle damage, and many more. They have proposed that further research is needed to understand the behavior of stem cells after transplantation and the processes of stem cell interaction with the diseased/injured milieu before stem cell treatments may be used in the clinical context [25].

One well-known clinical use of stem cell transplantation is bone marrow transplantation (BMT). Our primary defense against endogenous cancer cells is BMT, which may replenish the marrow and restore all blood cell types following large doses of chemotherapy and/or radiation. For numerous other clinical uses, more stem and progenitor cells are currently being isolated [26].

7. Stem Cell based therapies

Therapies based on stem cells have a lot of promise as innovative therapeutic agents to repair and regenerate wounded or damaged tissues. Different adult stem cells, as well as embryonic and iPSC stem cells, are currently being employed to treat a variety of illnesses worldwide. HSCs are the most often used stem cell type in clinical settings since they have been widely used in bone marrow transplants for the past 60 years to treat a variety of blood diseases and haematological cancers [27]. The area of stem cell biology was introduced in the 1960s when Tim and McCulloch identified two characteristics of HSCs: (i) they can self-renew, and (ii) they can produce all kinds of blood cells [17]. On the other hand, mature tissues like bone marrow include adult human stem cells (hematopoietic, mesenchymal). Adult stem cells' plasticity likely allows them to produce cell lineages distinct from those of their originating organ. Therefore, these cells can be utilized in humans and other species for cellular repair and organ regeneration [28].

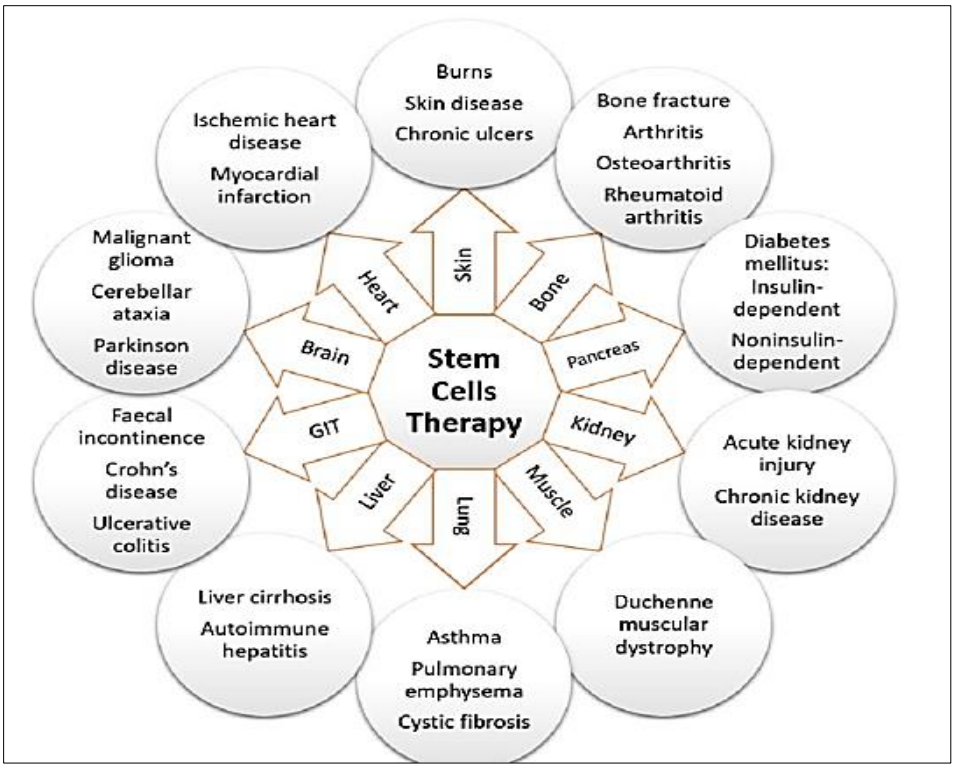

Figure 6 Various Stem cell-based therapies [2]

It is obvious that stem cell-based treatments present novel safety issues that cannot be resolved by typical analytical techniques created for other biopharmaceuticals or low-molecular-weight medications. Since the cells may become almost identical to the host cells after administration, monitoring cell biodistribution presents a unique challenge. An objective evaluation of risk in terms of tumorigenicity or improper ectopic tissue formation depends on the therapeutic cells' capacity to be tracked [29]. Despite continuous discussion about the type of cells utilized and their exact function

in vascular regeneration, cell therapy advanced quickly from the bench to the effort at translation to the bedside, with the first clinical trials employing BMCs starting in 1999. According to preliminary pilot trials, administering these cells in the setting of a recent MI seems to be safe and linked to better left ventricular function and blood flow. After extensive basic research and reliable, repeatable preclinical evidence, appropriate clinical trials are typically conducted [30].

The best interventions available are used to produce clinical benefits, and when the outcomes improve over time, they establish a new benchmark for care. Stem cell therapy's initial clinical trials finally produced a range of encouraging and disheartening unfavourable outcomes. But every trial that follows raises new issues that can be investigated or from which improved techniques might be created. It is imperative that scientists and those who assist them courageously adopt a long-term perspective on the goals of science and how they relate to treatment [21]. It is therefore necessary to transplant differentiated cardiac cells into hearts to assess the impact of these cells on heart function. Successful engraftment and differentiation into cardiomyocytes, vascular endothelium, and smooth muscle cells, as well as an enhanced ejection fraction and decreased fibrosis, were the outcomes of injecting iPSs into the rat heart [31].

7.1. Brain and spinal cord injury

Cell death results from traumatic brain damage and stroke. It is distinguished by the death of brain oligodendrocytes and neurons. In 2013, a modest clinical experiment was being conducted in Scotland where stroke victims received injections of stem cells into their brains. Numerous animal models have been used to study the cellular and molecular processes that follow SCI. Although translocation lesions in animal models can be replicated, their therapeutic applicability is debatable since they differ from the majority of SCIs in humans, namely crush traumas. However, animal models of contusion and crush do result in a histological image that is similar to the normal pathophysiology of SCI in people [32].

7.2. Wound healing

It is also possible to employ stem cells to promote the development of human tissues. Scar tissue replaces injured tissue in adults. Disorganized collagen structure, hair follicle loss, and uneven vascular structure are characteristics of scar tissue in the skin. When fetal tissue is injured, stem cells work to replace the damaged tissue with healthy tissue. Placing adult stem cells at the region of damaged tissue and letting them promote differentiation in the tissue bed cells is one potential technique for adult tissue regeneration. This technique produces a regenerative response that is more akin to fatal wound healing than the creation of adult scar tissue [15]. As a result of its potential to treat wounds that do not heal, stem cell therapies have become a fascinating area of study. Notably, damaged or diminished stem cell populations are a characteristic of these wounds. The ability of stem cells to self-renew and differentiate into multiple cell types is one of their special qualities. Furthermore, stem cells have the ability to increase the release of growth factors and cytokines required for immunomodulation and regeneration—two essential aspects of the pathophysiology of chronic wound healing that are not sufficiently addressed [33].

7.3. Intra-myocardial Cell-Based Therapy

According to certain preclinical research, bone marrow stem cells both locally and remotely support heart function and reverse remodelling following ischemia injury. To present, investigations have either infused or injected bone marrow stem cells into revascularization-undergoing regions. According to preclinical research, Bolli's team found that to fully assess the therapeutic potential of cell therapy, several treatments are required. In their investigation, cardiac mesenchymal cells were percutaneously infused into the left ventricular cavity in mice that had suffered a myocardial infarction in one or three treatments spaced 14 days apart [25]. Phase I human trials of stem-cell treatment for ischemic heart disease are starting to show some promising outcomes. In one study, ten MI patients received both bypass surgery and an injection of skeletal myoblasts from the musculus vastus lateralis into the scar left by the MI. 60% of the treated ischemic myocardium had thicker ventricular walls because of the combination therapy, which also enhanced systolic performance. This combined therapy was generally safe and effective as well, albeit four patients experienced mild ventricular tachycardia, which was likely brought on by the stem-cell transplant. Larger, multicentre, randomized, controlled studies that do not include concurrent revascularization are necessary before firm findings regarding the advantages of the stem-cell therapy itself can be made [34].

7.4. Bone marrow transplantation as therapy

Different cell types with distinct behaviours and functions make up bone marrow. Bone marrow cells can be transplanted as a distinct subpopulation of BMSCs or as whole, unfractionated bone marrow. Due to its easy accessibility, autologous origin, and capacity to transdifferentiate into either vascular or cardiac cells, bone marrow has lately drawn interest as a possible source of multipotent stem cells treating cell cardiomyopathy [26]. While there are numerous similarities between human and murine hematopoiesis, human HSCs' immunophenotypic markers (Lineage−

CD34+ CD38−) are different from those of their functionally equivalent mouse counterparts. Significant immunological obstacles must be removed for allogeneic transplantation therapy to be successful in humans, in contrast to inbred mouse strains that are genetically and immunologically similar. In patient's is made possible by the identification of the HLA system of MHC class I and II receptors, which bind to T-cell antigen receptors. Immunosuppression is used both during and after the transplantation of allogeneic stem cells from unrelated and related volunteers to support this [35]. The development of stem cell transplantation therapy has centered on studies to increase the number of donors available to patients. Haploidentical transplantation is now a therapeutic possibility while reducing the immunological effects of graft-versus-host disease because to the use of cord blood units as a source of stem cells and newly created precondition and immunosuppressive regimens. Patients who would not otherwise have a donor or related source of stem cells are increasingly receiving them thanks to these techniques [36].

7.5. Therapeutic Alternatives in Advanced Heart Failure

The treatment of advanced regional contraction insufficiency and severe global heart failure is based on nonpharmacological therapies, with the exception of pharmacotherapeutics and other methods. The goals of these procedures are to unload the heart (cardiac assist device), restore ventricular geometry by reducing the size of the ventricle (myocardial left ventricular resection), eliminate harmful volume overload in mitral incompetence (mitral valve repair), or synchronize the electrical and mechanical course of contraction and relaxation (ventricular synchronization) [37]. The search for alternative therapeutic strategies that may positively influence the disease's natural course is justified by the clinical limits of all these techniques, which are intended to lower myocardial oxygen consumption and systolic wall stress. It may be feasible to restore damaged and scarred tissue and subsequently improve ventricular function by stem cell-derived de novo repair of damaged cells. It is possible to hypothesize that future treatment choices including integrated therapeutical techniques, such as myocardial stem cell regeneration and ventricular resynchronization, may produce additive therapeutic benefits [38].

7.6. Stem Cell Therapies in Cardiovascular Disease

There are currently both cardiogenic and non-cardiogenic stem-cell tissue patches available for the healing of myocardial infarction in addition to stem cell injection therapy. Non-cardiogenic tissue patches composed of endothelial progenitor cells, bone marrow-derived stem cells, or skeletal myoblasts have been used in recent research to heal injured hearts. For the treatment of myocardial infarction in rats and dilated cardiomyopathy in hamsters, it has been demonstrated that the implantation of tissue sheets made of skeletal myoblasts is more beneficial than the injection of a cell suspension [35]. Additionally, a number of techniques for cardiogenic cardiac tissue-engineering have been created for use with primary neonatal cardiomyocytes. These include the epicardial implantation of a tissue-engineered cardiac patch and the injection of a combination of bioactive hydrogels and cells, followed by in situ cell-hydrogel polymerization [39].

Because heart muscle has a very limited capacity for regeneration, losing heart muscle—most frequently due to myocardial infarction can be fatal. Mouse lineage tracing has been used to question and disprove claims that the heart has specialized stem cells that can extensively replenish those lost [37]. Cardiomyocyte turnover in the human adult heart does occur, but it happens slowly (less than 1% annually), in stark contrast to the cardiomyocyte turnover in the hearts of zebrafish and neonates in mice, according to research on carbon labelling in humans (due to unintentional exposure to fallout from nuclear-bomb testing) [36].

8. Conclusion

Stem cell therapy is the future of regenerative medicine. Their ability to self-renew and differentiate into distinct cell types makes them a desirable alternative for the treatment of a number of diseases. Despite advances in stem cell biology and stem cell-based therapeutics, difficulties persist. For broad acceptance, these therapies must be safe, effective, and scalable. To overcome these obstacles and completely actualize stem cell therapy, more research is needed. Our study of stem cell biology will lead to new treatments for incurable diseases, increasing human health and quality of life. The future of stem cell therapy is promising, and it is likely that ongoing research will reveal new applications and therapies, thereby revolutionizing the field of regenerative medicine.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Kumar S, Singh NP. Stem cells: A new paradigm. Indian Journal of Human Genetics 2006 Apr 25;8(1):5-10.

[2] Jagiri AG, Gotte P, Singireddy S, Kadarla RK. Stem Cell Therapy-An Overview. Asian Journal of Pharmaceutical Research and Development. 2019 Oct 15;7(5):92-102.

[3] Alison MR, Poulsom R, Forbes S, Wright NA. An introduction to stem cells. The journal of pathology: a journal of the pathological society of great britain and ireland. 2002 Jul;197(4):419-23.

[4] Zakrzewski W, Dobrzyński M, Szymonowicz M, Rybak Z. Stem cells: past, present, and future. Stem cell research & therapy. 2019 Dec; 10;16(7)2-22.

[5] Hoang DM, Pham PT, Bach TQ, Ngo AT, Nguyen QT, Phan TT, Nguyen GH, Le PT, Hoang VT, Forsyth NR, Heke M. Stem cell-based therapy for human diseases. Signal transduction and targeted therapy. 2022 Aug 6;7(1):3-41.

[6] Poliwoda S, Noor N, Downs E, Schaaf A, Cantwell A, Ganti L, Kaye AD, Mosel LI, Carroll CB, Viswanath O, Urits I. Stem cells: a comprehensive review of origins and emerging clinical roles in medical practice. Orthopedic reviews. 2022 Aug 25;14(3):2-9.

[7] Aly RM. Current state of stem cell-based therapies: an overview. Stem cell investigation. 2020 May 15; 7(8):2-10.

[8] Mousaei Ghasroldasht M, Seok J, Park HS, Liakath, Al-Hendy A. Stem cell therapy: from idea to clinical practice. International journal of molecular sciences. 2022 Mar 5;23(5):2-21.

[9] Shamsuddin SA, Chan AM, Ng MH, Yazid MD, Law JX, Idrus RB, Fauzi MB, Yunus MH, Lokanathan Y. Stem cells as a potential therapy in managing various disorders of metabolic syndrome: a systematic review. American Journal of Translational Research. 2021 Nov 15;13(11):12217-12227.

[10] Tarik S, Kukloria S, Kayande N. A review on stem cell therapy in treatment of different disease. 2021 May 21;10(8):1439-1450.

[11] Bajada S, Mazakova I, Richardson JB, Ashammakhi N. Updates on stem cells and their applications in regenerative medicine. Journal of tissue engineering and regenerative medicine. 2008 Jun;2(4):169-83.

[12] Swami AA, Bhide AR, Anuhya K, Tharuni J, Vyawahare VM. Stem Cell Therapy-Current Scenario, Challenges and Future in India: A Review. VIMS Health Science Journal. 2023 Jun 30;10(2):61-67.

[13] Cerneckis J, Cai H, Shi Y. Induced pluripotent stem cells (iPSCs): molecular mechanisms of induction and applications. Signal Transduction and Targeted Therapy. 2024 Apr 26;9(1):2-26.

[14] Verma S, Arya S, Aman R. A review on medicinal plants in north region of India: traditional use in Vedic culture and their pharmacological properties. TMR Integr Med. 2022 Jul 10;21(6):63-66.

[15] Rouf M, Karnain O. Stem cells and their potential therapeutic applications. International Journal of Advanced Research in Biological Sciences. 2016;3(4):63-70.

[16] Varpe T. Therapeutic potential of stem cells: a comprehensive review (2025) May 19;3(2):991-998.

[17] Khandpur S, Gupta S, Gunaabalaji DR. Stem cell therapy in dermatology. Indian Journal of Dermatology, Venereology and Leprology. 2021 Oct 23;87(6):753-67.

[18] Boopalan D, Pandian R, Kesavan G. Prospects for Stem Cell-Based Regenerative Therapies in India. Stem Journal. 2021 Jun 17;3(1):11-21.

[19] Chakraborty D, De A. Stem-cell therapy in dermatology–Challenges and opportunities. Indian Journal of Skin Allergy. 2024 Jul 12;3(2):93-105.

[20] Strauer BE, Kornowski R. Stem cell therapy in perspective. Circulation. 2003 Feb 25;107(7):929-34.

[21] Sahni V, Kessler JA. Stem cell therapies for spinal cord injury. Nature Reviews Neurology. 2010 Jul;6(7):363-72.

[22] Raghuram AC, Roy PY, Lo AY, Sung CJ, Bircan M, Thompson HJ, Wong AK. Role of stem cell therapies in treating chronic wounds: A systematic review. World Journal of Stem Cells. 2020 Jul 26;12(7): 659-675.

[23] Goldring CE, Duffy PA, Benvenisty N, Andrews PW, Ben-David U, Eakins R, French N, Hanley NA, Kelly L, Kitteringham NR, Kurth J. Assessing the safety of stem cell therapeutics. Cell stem cell. 2011 Jun 3;8(6):618-28.

[24] Sieveking DP, Ng MK. Cell therapies for therapeutic angiogenesis: back to the bench. Vascular Medicine. 2009 May;14(2):153-66.

[25] Terashvili M, Bosnjak ZJ. Stem cell therapies in cardiovascular disease. Journal of cardiothoracic and vascular anesthesia. 2019 Jan 1;33(1):209-22.

[26] Rosenstrauch D, Poglajen G, Zidar N, Gregoric ID. Stem cell therapy for ischemic heart failure. Texas Heart Institute Journal. 2005 Aug 14;32(3):339-347.

[27] Ng AP, Alexander WS. Haematopoietic stem cells: past, present and future. Cell death discovery. 2017 Feb 6;3(1):1-4.

[28] Chen Y, Cheng RJ, Wu Y, Huang D, Li Y, Liu Y. Advances in stem cell-based therapies in the treatment of osteoarthritis. International Journal of Molecular Sciences. 2023 Dec 28;25(1):394-403.

[29] Dhakad GG, Fate BO, Pandav AR, Shrirao AV, Kochar NI, Chandewar AV. Review on Stem Cell Therapy and its Various Aspects. Research Journal of Pharmacology and Pharmacodynamics. 2023 Feb 12;15(2):77-86.

[30] Leventhal A, Chen G, Negro A, Boehm M. The benefits and risks of stem cell technology. Oral diseases. 2011 Nov 18;18(3):209-222.

[31] Wang J, Deng G, Wang S, Li S, Song P, Lin K, Xu X, He Z. Enhancing regenerative medicine: the crucial role of stem cell therapy. Frontiers in Neuroscience. 2024 Feb 21;14(8)239-248.

[32] Seok J, Park HS, Liakath Ali FB, Al-Hendy A. Stem cell therapy: from idea to clinical practice. International journal of molecular sciences. 2022 Mar 5;23(5):2-17.

[33] Charitos IA, Ballini A, Cantore S, Boccellino M, Di Domenico M, Borsani E, Nocini R, Di Cosola M, Santacroce L, Bottalico L. Stem cells: a historical review about biological, religious, and ethical issues. Stem Cells International. 2021 Dec 15;7(1):1748-1760.

[34] Gupta DR, Singh S. Stem cells: Current applications and future prospects. Indian Journal of Medical Sciences. 2024 Feb 7;76(1):740-749.

[35] Alenzi FQ, Lotfy M, Tamimi WG, Wyse RK. Stem cells and gene therapy. Lab. Hematol. 2010 Sep 1; 16:53-73.

[36] Agius CM and Blundell R. What Are Stem Cells? -Review Paper 2007 Jan 10;4(3):145-150.

[37] Tandon V, Kondapurkar US, Chowda HK, Kumar A. Regenerative Medicine and Stem Cell Therapy: An Evolving Paradigm in Modern Healthcare. European Journal of Cardiovascular Medicine. 2024 Apr 1;14(2):4-10.

[38] Khatun M. A Comprehensive Review of the Characteristics and Therapeutic Potential of Multipotent Stem Cells 2023 Mar 15;6(4):105-111.

[39] Manwar GG, Kalamb VS and Malthankar AS. A Brief Review on Stem Cells 2024 Nov 5;16(1):28-39.