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Animal Health

Review article

Application of Bovine Stem Cells and their Implications for Animal and Human Health

Lidyce Quesada Leyva *, José A. Betancourt Bethencourt *, Zaddys Ahimara Ruiz Hunt *

*University of Medical Sciences. Center of Immunology and Biologicals. Camagüey. Cuba.
Correspondence: betanster@gmail.com

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ABSTRACT

Background: Cattle are fundamental to food security, the global economy, and environmental sustainability, providing food, employment, and ecosystem services. Research on bovine stem cells has emerged as an innovative biotechnology tool, with applications ranging from regenerative medicine to cultured meat production, addressing challenges in both animal and human health. **Aim.** To systematically review the applications of bovine stem cells, their mechanisms, benefits, risks, and recent advances, as well as their implications for veterinary and human health. **Method:** A review of scientific literature (last 10 years) was conducted using databases such as PubMed, Scopus, and Web of Science, with search terms like "Bovine stem cells" and "Stem cell therapy in veterinary medicine." Peer-reviewed articles in English and Spanish were included, focusing on cell sources, clinical applications, and ethics. **Results:** Sources and types Bovine stem cells include embryonic (pluripotent ESCs), fetal (multipotent), adult (bone marrow, adipose tissue), and iPSCs (reprogrammed). Veterinary applications Treatment of arthritis, spinal cord injuries in animals, and cloning of elite specimens. Applications in humans Models for osteoarthritis, 3D bioprinting of tissues, and cancer therapies (CAR-T). Benefits Tissue regeneration, inflammation reduction, and alternatives to invasive surgeries. Risks Tumorigenicity, immune rejection, and lack of standardized protocols. Advances Gene editing with CRISPR, organoids to study mastitis, and sustainable cultivated meat. **Conclusions:** Bovine stem cells represent a bridge between veterinary and human medicine, with advances such as 3D bioprinting and cloning. Challenges remain, including protocol standardization, economic accessibility, and ethical dilemmas (use of embryos, regulation of cultured meat). Future research should prioritize interdisciplinary collaboration, integration of artificial intelligence, and global regulatory frameworks to maximize their impact on health and sustainability.

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INTRODUCTION

Cattle play a crucial role in agriculture and the global economy, providing not only nutritious food such as meat and milk but also essential products like leather and fertilizers. Their significance can be broken down into several aspects:

a) Food security, as it significantly contributes to human diets by providing high-quality proteins. Meat and milk are important sources of essential nutrients, such as proteins, vitamins, and minerals.

b) Environmental impact of livestock, there is evidence suggesting that proper grazing management can contribute to the restoration of degraded ecosystems. Livestock can help control desertification and improve soil health.

c) A vital source of employment and livelihood for millions of people worldwide. In Latin America, for example, it is estimated that 81 million people directly depend on livestock production. Research on cattle has led to innovations in animal production, including improvements in health and productivity through advanced techniques such as genetic selection and the use of stem cells (FAO, 2024).

Stem cell research in the context of cattle has made significant progress, opening new possibilities for agricultural biotechnology, such as: a) Cultivated meat production, b) Genetic preservation, c) Induced Pluripotent Stem Cells (iPSCs), d) Regenerative biotechnology (García Pedraza, 2024).

In summary, both cattle and advances in stem cell research are essential for addressing global challenges related to food, sustainability, and animal health (Han et al., 2024; Kumar *et al.*, 2021).

Stem cells are a special type of cell that have the ability to self-renew and differentiate into various types of specialized cells. These properties make them a fundamental area of research in biology and medicine (Zhao *et al*., 2021).

There are several types of stem cells: a) Embryonic stem cells (ESCs): They come from embryos in the early stages of development, specifically from the blastocyst, which is between 3 and 5 days old. These cells are pluripotent, meaning they can develop into almost any type of cell in the human body, allowing the regeneration of damaged tissues and organs, adult embryonic cells (AECs): Found in specific tissues of adults, children, and fetuses. These cells are also known as tissue-specific stem cells. They are generally multipotent, meaning they can differentiate into several cell types, but are limited to the types of cells from the tissue they originate from. For example, hematopoietic stem cells can generate different types of blood cells, c) Induced pluripotent stem cells (iPSCs): Adult cells that have been genetically reprogrammed to acquire properties similar to those of embryonic stem cells. Like ESCs, iPSCs are pluripotent and can differentiate into almost any cell type. They have the ability to divide indefinitely to produce more stem cells and transform into different specialized cell types, which is crucial for tissue development and repair (Barfoot *et al*., 2017; Olenic *et al*., 2024).

Stem cells have vast potential in various areas:

- ✓ Regenerative medicine: They can be used to regenerate damaged or diseased tissues, showing promise for the treatment of conditions such as diabetes, heart diseases, and spinal cord injuries (Ruiz *et al*., 2024).
- ✓ Biomedical research – They provide models for studying human development and diseases, as well as for testing new treatments (Barrera *et al*., 2007).
- ✓ Cell Therapies: Stem cell-based treatments are being explored for hematological diseases, such as leukemias and bone marrow-related disorders (Hong, 2022; Quesada Leyva *et al*., 2017).

The study of stem cells is a dynamic field with significant implications for modern medicine, offering potential solutions to complex and challenging medical problems.

This review aims to present the application of bovine stem cells and their implications for animal and human health.

DEVELOPMENT

This article presents a systematic review of the scientific literature on peer-reviewed articles published in the last ten years, in English and Spanish, focusing on the application of bovine stem cells and their impact on animal and human health. Scientific databases such as PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar were consulted using search terms like "Bovine stem cells," "Cattle stem cell applications," "Stem cell therapy in veterinary medicine," "Bovine stem cells in human health," and "Ethical implications of bovine stem cells."

The review covered the following topics:

- ✓ Mechanisms of action of stem cells;
- ✓ Sources and types of stem cells derived from cattle
- ✓ Applications of these stem cells in veterinary and human medicine.
- ✓ Benefits and risks associated with their use.
- ✓ Recent advances have been made in this field.
- ✓ The references analyzed trends, significant advances, and gaps in research.

Mechanisms of action of stem cells;

Stem cells have the unique ability to self-renew and differentiate into various cell types, allowing them to play a crucial role in tissue regeneration and repair (Yang *et al*., 2023). These cells can divide symmetrically (producing two stem cells) or asymmetrically (producing one stem cell and one differentiated cell). Asymmetric division is essential to maintaining the stem cell population while generating specialized cells. Self-renewal and differentiation are regulated by transcription factors such as NANOG, OCT3/4, and SOX2, which preserve the undifferentiated state of stem cells. Telomerase activity also plays a vital role by enabling stem cells to divide indefinitely without aging (Molnar *et al*., 2022).

Platelet-Rich Plasma (PRP) is a serum product obtained through centrifugation or filtration, increasing platelet concentration compared to normal plasma. When activated *in vivo* by inflammation, calcium chloride, thrombin, or cell lysis, platelets release numerous growth factors and immunomodulatory cytokines. The growth factors in PRP promote mesenchymal and epithelial cell proliferation, type I collagen production, angiogenesis, and differentiation of local progenitor cells, accelerating the healing process of injured tissues. Additionally, Conditioned Autologous Serum (CAS) is primarily used to modulate inflammatory cytokine signaling in osteoarthritis. Another recent treatment, Autologous Protein Solution (APS), concentrates platelets, growth factors, and anti-inflammatory cytokines through centrifugation and activation with polyacrylamide beads (Jaya Baquero, 2024; Tornero-Tornero & Fernández Rodríguez, 2021).

Stem cells reside in a specific microenvironment known as the "niche," where they interact with other cell types and soluble factors. This interaction is crucial for regulating their behavior, as the niche provides signals that can activate or inhibit self-renewal and differentiation processes. Growth factors and cytokines released by niche cells influence the proliferation and differentiation of stem cells (Yang *et al*., 2023).

Stem cells can release various molecules that act on themselves (autocrine effect) or on neighboring cells (paracrine effect). These factors include cytokines, chemokines, and growth factors, which are essential for cell migration, proliferation, and differentiation. Mechanisms such as autophagy allow stem cells to remove damaged components and maintain their cellular integrity. This process is crucial for stem cells to enter a proper resting state, preventing premature exhaustion (Chirveches, 2024).

In some cases, stem cells can differentiate into a cell type different from the one they normally produce. This phenomenon, known as transdifferentiation, allows stem cells to adapt to various physiological or pathological contexts, integrating into the surrounding tissue and participating in regenerative processes (Salazar-Villegas, 2024).

Sources and types of stem cells derived from cattle

Bovine stem cells are obtained from various sources and are classified based on their origin and differentiation potential. Below are the main sources and types:

- ✓ Embryonic stem cells (ESCs): They are extracted from blastocysts (embryos in early stages of development, around days 5-7). They are pluripotent, which allows them to differentiate into any cell type in the organism, including muscle, cardiac, liver, and neuronal cells. They are used in research for cloning, tissue production, and embryonic development studies.

Studies are being conducted on the ethical and legal framework that regulates these development models. (Alomar and Erbaş, 2024)

- ✓ Fetal stem cells: Derived from developing bovine fetal tissues. They have a more limited differentiation potential than ESCs, but they are still multipotent, capable of generating cells for specific tissues such as bone, cartilage, or muscle. Used in regenerative medicine to treat diseases such as arthritis or musculoskeletal injuries in animals and humans (Kaptan & Erbaş, 2024).
- ✓ Adult stem cells:
  - Bone marrow: They produce blood cells and immune system cells (Toco *et al*., 2024).
  - Adipose tissue (fat): Used to regenerate tissues such as muscle or cartilage (Sánchez-Leal *et al.*, 2024).
- ✓ Induced pluripotent stem cells (iPSCs) (Cerneckis *et al*., 2024) Adult somatic cells (e.g., skin cells) genetically reprogrammed to acquire pluripotency. Pluripotent, similar to ESCs, but without the need to use embryos, which reduces ethical dilemmas.
- ✓ Umbilical cord blood: Although less common in cattle, it is a potential source of hematopoietic stem cells (Solís *et al*., 2018).

Bovine stem cells not only revolutionize veterinary and human medicine (e.g., regenerative therapies), but also offer sustainable solutions for livestock farming, such as the production of cultivated meat or the preservation of genetic biodiversity. However, its development requires overcoming technical and ethical challenges to ensure safe and responsible applications.

Applications of stem cells in veterinary and human medicine

Bovine stem cells have demonstrated significant potential in both fields, with applications ranging from tissue regeneration to biotechnology innovation. Below are the main uses:

Bovine stem cells are mainly used for the treatment of diseases and injuries in animals, including:

- ➢ Musculoskeletal diseases: Hip dysplasia and arthritis: Mesenchymal stem cells (MSCs) derived from adipose tissue or bone marrow reduce inflammation and regenerate cartilage, improving mobility in dogs and horses. Tendon and ligament injuries: They accelerate healing in horses with tendinitis and desmitis, improving the quality of the regenerated tissue (Fortier & Travis, 2011).

A large number of musculoskeletal diseases affect a significant portion of the global population from birth to death. Countless pathological diseases and traumatic injuries (both acute and chronic) contribute to various human disabilities, causing a tremendous financial burden on the healthcare economy. The medical field is continuously seeking new ways to combat orthopedic-related diseases. The immediate goal is the restoration of anatomy and, ultimately, the recovery of function, with the hope of improving quality, if not quantity, of life. Traditional methods involve the surgical correction/reconstruction of skeletal deformities caused by fractures, damage, or soft tissue rupture, or the replacement/resection of degenerated joints. Modern research is currently focused on innovative procedures to replenish/restore the human body to a state close to its original/natural condition (Zumwalt & Reddy, 2020).

- Neurological pathologies: primary neurological conditions, including Parkinson's disease (PD), Alzheimer's disease (AD), amyotrophic lateral sclerosis (ALS), multiple sclerosis (MS), stroke, spinal cord injury (SCI), and other related disorders. The review begins with a detailed introduction to stem cell biology, discussing the types, sources, and mechanisms of action of stem cells in neurological therapies. Then, it critically examines preclinical evidence from animal models and early human trials investigating the safety, feasibility, and efficacy of different types of stem cells, such as embryonic stem cells (ESCs), mesenchymal stem cells (MSCs), neural stem cells (NSCs), and other stem cells (Rahimi Darehbagh *et al.*, 2024).

Spinal cord injuries and disc degeneration: They promote the repair of nervous tissue in dogs and cats, improving motor function. (Feijo, 2024)

- Internal diseases: Kidney and liver failure: They help regenerate damaged tissues, such as in cases of chronic hepatitis or kidney disease in pets and humans (José Antonio *et al*., 2024).
- Diabetes mellitus: Studies in dogs show improvements in insulin secretion when using MSCs derived from adipose tissue. (Ghoneim *et al.*, 2024)
- Applications in livestock: Reproductive improvement: Cloning of animals with superior genetic traits using embryonic stem cells (ESCs). (Goszczynski *et al.*, 2023)

Sustainable production: Development of *in vitro* cultivated meat to reduce environmental impact (Soleymani *et al*., 2024).

Applications in human medicine:

- Bovine MSCs serve as a model for studying cartilage repair in human osteoarthritis, thanks to their biological similarity (Focsa *et al.*, 2024).
- Biotechnology and pharmaceutical production: Use of bovine stem cells to produce therapeutic proteins or growth factors applicable in human treatments (Takematsu *et al*., 2022).
- Studies in cattle allow for testing regenerative therapies before their application in humans, especially in areas such as tissue engineering (Park *et al*., 2024).

Cross-cutting benefits:

- Anti-inflammatory properties: MSCs secrete cytokines that modulate the immune response, useful in autoimmune diseases such as inflammatory bowel disease.
- Chronic pain reduction: Analgesic effect in patients with osteoarthritis or degenerative injuries. - Alternative to invasive surgeries: Lower risks and faster recovery compared to traditional methods (Salari *et al*., 2020).

- Ethical aspects: Use of embryos in research and animal welfare in livestock applications (Quesada Leyva *et al*., 2021).

Future and perspectives:

Advances in genetic engineering: Modification of stem cells to enhance their therapeutic efficacy.

- Combined therapies: Use of MSCs with platelet-rich plasma (PRP) to enhance regeneration.
- Regulation and standards: The need for clear legal frameworks to ensure safety and transparency, both in veterinary and human medicine (Gupta & Singh, 2024). Bovine stem cells are a versatile tool with transformative applications in veterinary medicine (treatment of dysplasia, spinal cord injuries) and human medicine (research models, biotechnology). However, its success depends on overcoming technical and ethical challenges, as well as consolidating standardized protocols. Collaboration between both medical fields promises to accelerate innovations that benefit both animals and humans (Muniz *et al.*, 2024; Özaydın *et al*., 2024; Talavera *et al.*, 2017).

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Benefits of stem cell use

a) Regenerative medicine: Stem cells have the ability to transform into different types of specialized cells in the body, making them a valuable resource for regenerative medicine.

b) Skin improvement: In facial treatments, stem cells stimulate the production of collagen and elastin, contributing to firmer, more elastic, and rejuvenated skin. They also help reduce wrinkles and fine lines, improving skin texture and elasticity.

c) Tissue regeneration: They promote cellular renewal, repairing skin damage and strengthening its structure.

d) Treatment of musculoskeletal injuries and diseases: In traumatology and orthopedic surgery, stem cells are a promising tool for treating musculoskeletal injuries and diseases, accelerating bone consolidation in complex fractures.

e) Pain reduction: The new cartilage tissue generated by stem cells can reduce pain and act as an anti-inflammatory in diseases such as osteoarthritis (Quesada Leyva *et al.*, 2017; Vizoso *et al.*, 2023b).

Risks associated with stem cell therapy:

There is a risk that stem cells may become cancerous if they divide uncontrollably or differentiate into abnormal cells. The body may recognize foreign stem cells as a threat and attack them, causing inflammation and damage. They may lead to infections or other complications associated with invasive medical procedures. Additionally, they can interact unpredictably with other medications the patient is taking, potentially resulting in adverse drug interactions (Salazar-Villegas, 2024; Vizoso et al., 2023a).

There is a risk of encountering unethical professionals who offer untested or unverified stem cell therapies that are neither safe nor effective (Tornero-Tornero & Fernández Rodríguez, 2021).

Recent advances in stem cell therapies for bovines and humans

a) Regenerative medicine: Use of mesenchymal stem cells (MSCs) derived from adipose tissue or bone marrow to treat hoof and joint injuries in dairy cows, reducing lameness and improving productivity (Salazar-Villegas, 2024).

- 3D bioprinting of cartilage tissue from bovine MSCs to repair joint defects in livestock (Szychlinska *et al*., 2022).

b) Cloning and genetic improvement

- Cloning elite animals: using somatic cell nuclear transfer (SCNT) techniques to replicate bovines with high milk productivity or disease resistance. Modification of bovine stem cells to introduce genes for disease resistance, such as bovine tuberculosis or foot-and-mouth disease (Tristan *et al*., 2023).

c) Cultured meat production

- Development of bovine induced pluripotent stem cells (iPSCs) for producing lab-grown meat, reducing dependence on traditional livestock farming and methane emissions (Olenic *et al*., 2024; Soleymani *et al*., 2024).

d) Disease models

- Creation of bovine organoids (mini *in vitro* organs) from stem cells to study infectious diseases such as mastitis, accelerating treatment development (Gabriel *et al.*, 2024).

Advances in therapies for humans

a) Tissue and organ engineering

- 3D bioprinting of organs Use of human stem cells and biocompatible scaffolds to create functional tissues, such as skin or corneas, with potential for transplants. Brain organoids: Pluripotent stem cell-derived models for studying neurodegenerative diseases such as Alzheimer's (Edri *et al.*, 2024).

b) Cancer therapies: Genetic modification of hematopoietic stem cells to target cancer cells, with success in leukemias and lymphomas (Everette *et al*., 2023; Salazar, 2023).

- NK (Natural Killer) stem cells: Enhanced to combat solid tumors, such as breast or lung cancer (Coënon *et al*., 2024).

c) Personalized medicine Reprogramming patient cells to generate personalized disease models, such as muscular dystrophy or cystic fibrosis, testing drugs *in vitro* (Tello Vera, 2022).

- Cardiovascular therapies: Injection of MSCs into damaged hearts to regenerate myocardium after heart attacks, with Phase III clinical trials underway (Kumar *et al.*, 2024; Terzic & Perez-Terzic, 2010).

d) Overcoming immunological barriers

- "Universal" cells Editing human stem cells (via CRISPR) to remove HLA molecules, reducing rejection in transplants (Zheng *et al*., 2024).

Cross-species advancements (bovine-human)

- Use of bovine stem cells to test regenerative therapies before applying them in humans, leveraging anatomical similarities (e.g., cartilage repair studies) (Lee *et al*., 2024).
- Pharmaceutical biotechnology: Production of monoclonal antibodies and growth factors in bovine stem cell cultures, useful for treating human diseases such as rheumatoid arthritis (Gutiérrez-Chávez *et al*., 2024).
- Ethics and sustainability: Collaborative research to address common ethical dilemmas, such as the use of embryos or the regulation of cultivated meat (Cabezas, 2025; Quesada Leyva *et al.*, 2021; Quesada Leyva *et al.*, 2017; Salazar, 2023).

Future and perspectives:

- Artificial intelligence: Optimization of cell differentiation protocols using predictive algorithms (Vo *et al.*, 2024).
- Combined gene-cell therapies: Use of genetically edited stem cells to treat multifactorial diseases (Deneault, 2024).
- Global regulations: Harmonization of regulations to ensure safety in both veterinary and human applications (Han *et al.*, 2024; Talavera *et al.*, 2017).

A critical analysis based on the conducted literature review

1. Current trends

- Focus on induced pluripotent stem cells (iPSCs):
- Growing interest in reprogramming bovine somatic cells (e.g., fibroblasts) to generate iPSCs, avoiding embryo use and enabling applications such as cultivated meat production and genetic preservation.
- Use of CRISPR/Cas9 to edit iPSCs and enhance their differentiation into specific tissues (muscle, cartilage).
- Integration of advanced biotechnologies:
- Combination of stem cells with 3D bioprinting to create structured tissues (e.g., bovine cartilage for repairing joints in horses or humans).

- Development of bovine organoids as models to study infectious diseases (e.g., mastitis) or test drugs.

• Interspecies translation (One Health):

- Leveraging biological similarities between bovines and humans to validate regenerative therapies (e.g., cartilage repair in osteoarthritis) before applying them in human medicine.

• Sustainability and ethics:

- Research on cultivated meat to reduce the environmental impact of livestock farming.

- Debate on regulations for embryo use and animal welfare in livestock applications.

CONCLUSIONS

The study of bovine stem cells has proven to be a transformative field, with profound implications for both veterinary and human medicine. Key conclusions from this review:

1. Transformative Potential in Medicine:

Bovine stem cells, especially mesenchymal stem cells (MSCs) and induced pluripotent stem cells (iPSCs), have revolutionized the treatment of musculoskeletal diseases (arthritis, tendon injuries), neurological conditions (spinal cord injuries), and metabolic disorders (diabetes) in animals. In humans, they serve as preclinical models for regenerative therapies, such as cartilage repair in osteoarthritis or 3D bioprinting of tissues.

2. Technological innovation:

The integration of tools such as CRISPR/Cas9, 3D bioprinting, and bovine organoids has enabled unprecedented advancements, from gene editing for disease resistance to sustainable cultivated meat production, reducing the environmental impact of traditional livestock farming.

3. Interspecies synergies (One Health):

The biological similarity between bovines and humans facilitates the translation of veterinary findings into human medical applications. For example, studies on bovine cartilage repair have inspired protocols to treat osteoarthritis in human patients.

4. Critical challenges:

Technical barriers persist, such as low efficiency in cell differentiation and the lack of standardized protocols. Additionally, the risks of tumorigenicity and immune rejection require long-term safety studies.

Ethical dilemmas, such as embryo use and cloning, along with the high costs of therapies, limit their accessibility and global acceptance.

In summary, bovine stem cells represent a bridge between animal and human health, with the potential to revolutionize regenerative medicine, food production, and biodiversity conservation. However, its maximum impact will only be achieved by overcoming technical, ethical, and economic challenges through rigorous research and inclusive policies. This constantly evolving field requires a global commitment to ensure that its benefits reach both rural communities and public health systems.

REFERENCES

Alomar, R., & Erbaş, O. (2024). Stem Cells and Ethics. *Journal of Experimental and Basic Medical Sciences*, *5*(1), 164-169. https://jebms-org.translate.goog/full-text/173?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Barfoot, J., Doherty, K., & Blackburn, C. C. (2017). EuroStemCell: A European infrastructure for communication and engagement with stem cell research. Seminars in cell & developmental biology,

Barrera, J. B., González, J. L.-P., López, J. G.-F., & Cardoso, F. P. (2007). Células madre y cáncer: dilucidando el origen de la célula madre tumoral. *Revista de Medicina de la Universidad de Navarra*, 14-17. https://revistas.unav.edu/index.php/revista-de-medicina/article/view/7679/6724

Cabezas, M. R. (2025). Modelos embrionarios con células madre: una reflexión ético-jurídica pendiente. *Medicina y Ética*, *36*(1), 78-131. https://revistas.anahuac.mx/index.php/bioetica/article/view/2742/2765

Cerneckis, J., Cai, H., & Shi, Y. (2024). Induced pluripotent stem cells (iPSCs): molecular mechanisms of induction and applications. *Signal Transduction and Targeted Therapy*, *9*(1), 112. https://www.nature.com/articles/s41392-024-01809-0.pdf

Chirveches, A. P. (2024). Contribuciones fundamentales sobre el rol del tejido adiposo en el humano. *Cuadernos Hospital de Clínicas*, *65*(1), 67-76. http://www.scielo.org.bo/scielo.php?script=sci_arttext&pid=S1652-67762024000100067

Coënon, L., Geindreau, M., Ghiringhelli, F., Villalba, M., & Bruchard, M. (2024). Natural Killer cells at the frontline in the fight against cancer. *Cell Death & Disease*, *15*(8), 614. https://www-nature-com.translate.goog/articles/s41419-024-06976-0?error=cookies_not_supported&code=a01d27a2-0772-4cd9-ab83-4a4db8ddfffc&_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc#auth-Mannon-Geindreau-Aff2-Aff3

Deneault, E. (2024). Recent Therapeutic Gene Editing Applications to Genetic Disorders. *Current Issues in Molecular Biology*, *46*(5), 4147-4185. https://www-mdpi-com.translate.goog/1467-3045/46/5/255?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Edri, S., Newman Frisch, A., Safina, D., Machour, M., Zavin, J., Landsman, L., Pierreux, C. E., Spagnoli, F. M., & Levenberg, S. (2024). 3D Bioprinting of Multicellular Stem Cell-Derived Constructs to Model Pancreatic Cell Differentiation. *Advanced Functional*

Materials, 2315488. https://advanced-onlinelibrary-wiley-com.translate.goog/doi/epdf/10.1002/adfm.202315488?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Everette, K. A., Newby, G. A., Levine, R. M., Mayberry, K., Jang, Y., Mayuranathan, T., Nimmagadda, N., Dempsey, E., Li, Y., & Bhoopalan, S. V. (2023). Ex vivo prime editing of patient haematopoietic stem cells rescues sickle-cell disease phenotypes after engraftment in mice. *Nature biomedical engineering*, *7*(5), 616-628. https://www-nature-com.translate.goog/articles/s41551-023-01026-0?error=cookies_not_supported&code=a9885ee8-b2ed-48fa-9ae3-785807a32f68&_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

FAO. (2024). Producción Animal. https://www.fao.org/animal-production/es/

Feijo, M. E. A. (2024). Avances en Terapia Celular para la Rehabilitación Neuromuscular Canina: Revisión de Ensayos Clínicos y Evidencia Científica. *Ciencia Latina Revista Científica Multidisciplinar*, *8*(4), 10876-10889. https://ciencialatina.org/index.php/cienciala/article/view/13229

Focsa, M. A., Florescu, S., & Gogulescu, A. (2024). Emerging Strategies in Cartilage Repair and Joint Preservation. *Medicina*, *61*(1), 24. https://pmc.ncbi.nlm.nih.gov/articles/PMC11766557/pdf/medicina-61-00024.pdf

Fortier, L. A., & Travis, A. J. (2011). Stem cells in veterinary medicine. *Stem cell research & therapy*, *2*, 1-6. https://link.springer.com/article/10.1186/scrt50

Gabriel, V., Zdyrski, C., Sahoo, D. K., Ralston, A., Wickham, H., Bourgois-Mochel, A., Ahmed, B., Merodio, M. M., Paukner, K., & Piñeyro, P. (2024). Adult animal stem cell-derived organoids in biomedical research and the one health paradigm. *International journal of molecular sciences*, *25*(2), 701. https://www-mdpi-com.translate.goog/1422-0067/25/2/701?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

García Pedraza, E. (2024). Evaluación de la seguridad de la administración intraarticular única y repetida de células madre de cordón umbilical equino (EUC-MSC) en perros jóvenes y sanos. https://docta.ucm.es/entities/publication/247915c9-f8d3-4545-ada2-9b2df5e3a53a

Ghoneim, M. A., Gabr, M. M., El-Halawani, S. M., & Refaie, A. F. (2024). Current status of stem cell therapy for type 1 diabetes: a critique and a prospective consideration. *Stem cell research & therapy*, *15*(1), 23. https://stemcellres.biomedcentral.com/counter/pdf/10.1186/s13287-024-03636-0.pdf

Goszczynski, D., Navarro, M., & Mutto, A. (2023). Review: embryonic stem cells as tools for in vitro gamete production in livestock. Animal 17 (Suppl 1): 100828. https://www-sciencedirect-com.translate.goog/science/article/pii/S1751731123001246?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Gupta, D. R., & Singh, S. (2024). Stem cells: Current applications and future prospects. *Indian Journal of Medical Sciences*, 1-5. https://ijmsweb.com/content/101/2024/76/1/pdf/IJMS-76-002.pdf

Gutiérrez-Chávez, D., Gómez-Valencia, M. F., Reyes-Pérez, I. V., Arellano-García, M. E., & Torres-Bugarín, O. (2024). Anticuerpos monoclonales para el tratamiento de cáncer: Breve revisión panorámica. *Investigación y Ciencia de la Universidad Autónoma de Aguascalientes*(92). https://revistas.uaa.mx/index.php/investycien/article/view/4653

Han, H., Chen, B.-T., Liu, Y., Wang, Y., Xing, L., Wang, H., Zhou, T.-J., & Jiang, H.-L. (2024). Engineered stem cell-based strategy: A new paradigm of next-generation stem cell product in regenerative medicine. *Journal of Controlled Release*, *365*, 981-1003. https://www.sciencedirect.com/science/article/abs/pii/S0168365923008088

Hong, I.-S. (2022). Enhancing stem cell-based therapeutic potential by combining various bioengineering technologies. *Frontiers in Cell and Developmental Biology*, *10*, 901661. https://www.frontiersin.org/journals/cell-and-developmental-biology/articles/10.3389/fcell.2022.901661/full

Jaya Baquero, E. K. (2024). *Comparación del efecto terapéutico de células madres de líquido amniótico y plasma rico en plaquetas contra mastitis subclínica en ganado lechero*

José Antonio, C. A., Milagros, C. Q., Niurka, P. C., & Yelec, E. G. (2024). Terapia celular regenerativa. Retos y perspectivas en la cirrosis hepática. *Capítulo de Gastroenterología de la Provincia de Ciego de Ávila (Gastroávila 2024)*. https://gastroavila2021.sld.cu/index.php/gastroavila2024/2024/paper/viewFile/195/112

Kaptan, B., & Erbaş, O. (2024). Stem Cells in Surgery. *Journal of Experimental and Basic Medical Sciences*, *5*(1), 125-128. https://jebms-org.translate.goog/full-text/167?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Kumar, D., Talluri, T. R., Selokar, N. L., Hyder, I., & Kues, W. A. (2021). Perspectives of pluripotent stem cells in livestock. *World Journal of Stem Cells*, *13*(1), 1. https://pmc.ncbi.nlm.nih.gov/articles/PMC7859985/pdf/WJSC-13-1.pdf

Kumar, R., Mishra, N., Tran, T., Kumar, M., Vijayaraghavalu, S., & Gurusamy, N. (2024). Emerging Strategies in Mesenchymal Stem Cell-Based Cardiovascular Therapeutics. *Cells*, *13*(10), 855. https://www-mdpi-com.translate.goog/2073-4409/13/10/855?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Lee, H. J., Hossain, R., Baek, C.-H., Lee, C. J., & Hwang, S.-C. (2024). Intra-articular injection of stem cells for the regeneration of knee joint cartilage: a therapeutic option for knee osteoarthritis—a narrative review. *Biomolecules & Therapeutics*, *33*(1), 86. https://www-biomolther-org.translate.goog/journal/view.html?uid=1583&vmd=Full&&_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Molnar, V., Pavelić, E., Vrdoljak, K., Čemerin, M., Klarić, E., Matišić, V., Bjelica, R., Brlek, P., Kovačić, I., & Tremolada, C. (2022). Mesenchymal stem cell mechanisms of action and clinical effects in osteoarthritis: a narrative review. *Genes*, *13*(6), 949. https://www-mdpi-com.translate.goog/2073-4425/13/6/949?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Muniz, T. D. P. T. P., Rossi, M. C., de Vasconcelos Machado, V. M., & Alves, A. L. G. (2024). Mesenchymal stem cells and tissue bioengineering applications in sheep as ideal model. *Stem Cells International*, *2024*(1), 5176251. https://onlinelibrary-wiley-com.translate.goog/doi/10.1155/2024/5176251?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Olenic, M., Deelkens, C., Heyman, E., De Vlieghere, E., Zheng, X., van Hengel, J., De Schauwer, C., Devriendt, B., De Smet, S., & Thorrez, L. (2024). Livestock cell types with myogenic differentiation potential: considerations for the development of cultured meat. *animal*, 101242. https://doi.org/10.1016/j.animal.2024.101242

Özaydın, T., Tunç, K. C., & Erbaş, O. (2024). Revolutionizing Health Technologies: The Transformative Power of Stem Cells. *Journal of Experimental and Basic Medical Sciences*, *5*(1), 39-43. https://jebms-org.translate.goog/full-text/158?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Park, S., Rahaman, K. A., Kim, Y.-C., Jeon, H., & Han, H.-S. (2024). Fostering tissue engineering and regenerative medicine to treat musculoskeletal disorders in bone and muscle. *Bioactive Materials*, *40*, 345-365. https://www-sciencedirect-com.translate.goog/science/article/pii/S2452199X24002457?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Quesada Leyva, L., Gracia Barrios, C., & Fuentes Diaz, Z. (2021). Ética en el ámbito de la investigación en medicina regenerativa. *Revista Cubana de Hematología, Inmunología y Hemoterapia*, *37*(4). http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-02892021000400007

Quesada Leyva, L., León Ramentol, C. C., Fernández Torres, S., & Nicolau Pestana, E. (2017). Células madre: una revolución en la medicina regenerativa. *MediSan*, *21*(5), 574-581. http://scielo.sld.cu/pdf/san/v21n5/san09215.pdf

Rahimi Darehbagh, R., Seyedoshohadaei, S. A., Ramezani, R., & Rezaei, N. (2024). Stem cell therapies for neurological disorders: current progress, challenges, and future perspectives. *European Journal of Medical Research*, *29*(1), 386. https://eurjmedres-biomedcentral-com.translate.goog/articles/10.1186/s40001-024-01987-1?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Ruiz, E., Gil, A., & Allonca, A. (2024). Células Madre y La Terapia Regenerativa: De La Investigación a La Práctica. *Portal de Revista| Visión 360*, *3*(3), 21-24. http://portalrevista360escueladeenfermeria.com/index.php/vision360/article/view/55/53

Salari, V., Mengoni, F., Del Gallo, F., Bertini, G., & Fabene, P. F. (2020). The anti-inflammatory properties of mesenchymal stem cells in epilepsy: Possible treatments and future perspectives. *International Journal of Molecular Sciences*, *21*(24), 9683. https://www-mdpi-com.translate.goog/1422-0067/21/24/9683?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Salazar-Villegas, B. (2024). Avances de la medicina regenerativa, revisión de las investigaciones recientes en células madre. *Horizon Nexus Journal*, *2*(1), 46-61. https://horizonnexusjournal.editorialdoso.com/index.php/home/article/view/33/147

Salazar, M. M. (2023). Las Células Madre Mesenquimales Endometriales modificadas genéticamente como Terapia Celular para la Endometriosis. *Revista Iberoamericana de Fertilidad y Reproducción Humana*, *40*(1 Enero-Febrero-Marzo-Abril). https://revistafertilidad.com/index.php/rif/article/view/81

Sánchez-Leal, A., Noriega-Rodríguez, D., Montalvo-Benítez, O., Ramírez-Gómez, M., Angulo-Lugo, A., & Varona-Martin, J. D. (2024). Evaluación del tratamiento de quemaduras dérmicas profundas con células madre mesenquimales. *Revista de Ciencias Médicas de Pinar del Río*, *28*(4), e6501. http://scielo.sld.cu/pdf/rpr/v28n4/1561-3194-rpr-28-04-e6501.pdf

Soleymani, S., Naghib, S. M., & Mozafari, M. (2024). An overview of cultured meat and stem cell bioprinting: How to make it, challenges and prospects, environmental effects, society's culture and the influence of religions. *Journal of Agriculture and Food Research*, 101307. https://www-sciencedirect-com.translate.goog/science/article/pii/S2666154324003442?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Solís, M. C., Rodríguez, R. E., Quirós, S. R., Vargas, M. A. V., Cubillo, M. Z., & Román, J. J. M. (2018). Células madre de sangre de cordón umbilical: obtención, aplicaciones y situación en Costa Rica. *Revista Médica de la Universidad de Costa Rica*, *12*(1). https://revistas.ucr.ac.cr/index.php/medica/article/view/34612

Szychlinska, M. A., Bucchieri, F., Fucarino, A., Ronca, A., & D'Amora, U. (2022). Three-dimensional bioprinting for cartilage tissue engineering: insights into naturally-derived bioinks from land and marine sources. *Journal of Functional Biomaterials*, *13*(3), 118. https://www-mdpi-com.translate.goog/2079-4983/13/3/118?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Takematsu, E., Massidda, M., Auster, J., Chen, P.-C., Im, B., Srinath, S., Canga, S., Singh, A., Majid, M., & Sherman, M. (2022). Transmembrane stem cell factor protein therapeutics enhance revascularization in ischemia without mast cell activation. *Nature communications*, *13*(1), 2497.

Talavera, J., Gil-Chinchilla, J., García, D., Castellanos, G., López-Lucas, M., Atucha, N., & Moraleda, J. (2017). Terapia con células madre en medicina veterinaria: conceptos generales y evidencias clínicas. *Clínica veterinaria de pequeños animales: revista oficial de AVEPA, Asociación Veterinaria Española de Especialistas en Pequeños Animales*, *37*(2), 87-101. https://www.clinvetpeqanim.com/img/pdf/1329600056.pdf

Tello Vera, S. (2022). Tratamiento de fibrosis pulmonar idiopática con células madre adultas autólogas de médula ósea. *Revista Cubana de Hematología, Inmunología y Hemoterapia*, *38*(3). http://scielo.sld.cu/pdf/hih/v38n3/1561-2996-hih-38-03-e1651.pdf

Terzic, A., & Perez-Terzic, C. (2010). Terapia celular para la insuficiencia cardiaca. *Revista espanola de cardiologia*, *63*(10), 1117-1119. https://www.revespcardiol.org/es-terapia-celular-insuficiencia-cardiaca-articulo-13155716

Toco, I., Pérez, P., Velásquez, R., Velarde, J., Mamani, R., Carrasco, M., & Amaru, R. (2024). TRATAMIENTO EXITOSO DE LESIÓN DE MÉDULA ESPINAL CON CÉLULAS MADRES MESENQUIMALES DE MÉDULA ÓSEA. *Revista Médica La Paz*, *30*(2), 52-58. https://institutobiologiacelular.org/wp-content/uploads/2024/09/Tratamiento-exitoso-de-lesion-de-medula-espinal-con-celulas-madres-mesenquimales-de-medula-osea.-Agosto-2024.pdf

Tornero-Tornero, J., & Fernández Rodríguez, L. (2021). Plasma rico en plaquetas y células madre mesenquimales intrarticulares en artrosis. *Revista de la Sociedad Española del Dolor*, *28*, 80-84. https://scielo.isciii.es/pdf/dolor/v28s1/1134-8046-dolor-28-s1-0080.pdf

Tristan, C. A., Hong, H., Jethmalani, Y., Chen, Y., Weber, C., Chu, P.-H., Ryu, S., Jovanovic, V. M., Hur, I., & Voss, T. C. (2023). Efficient and safe single-cell cloning of human pluripotent stem cells using the CEPT cocktail. *Nature protocols*, *18*(1), 58-80. https://pmc.ncbi.nlm.nih.gov/articles/PMC11009857/pdf/nihms-1962556.pdf

Vizoso, F., Costa, L., & Eiro, N. (2023a). New era of mesenchymal stem cell-based medicine: Basis, challenges and prospects. *Revista Clínica Española (English Edition)*. https://www.sciencedirect.com/science/article/abs/pii/S0014256523001881

Vizoso, F., Costa, L., & Eiro, N. (2023b). Nueva era de la medicina basada en las células madre mesenquimales: bases, retos y perspectivas. *Revista Clínica Española*. https://www.sciencedirect.com/science/article/pii/S0014256523001881?via%3Dihub

Vo, Q. D., Saito, Y., Ida, T., Nakamura, K., & Yuasa, S. (2024). The use of artificial intelligence in induced pluripotent stem cell-based technology over 10-year period: A systematic scoping review. *Plos one*, *19*(5), e0302537. https://journals-plos-org.translate.goog/plosone/article?id=10.1371/journal.pone.0302537&_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Yang, G., Fan, X., Liu, Y., Jie, P., Mazhar, M., Liu, Y., Dechsupa, N., & Wang, L. (2023). Immunomodulatory mechanisms and therapeutic potential of mesenchymal stem cells. *Stem Cell Reviews and Reports*, *19*(5), 1214-1231. https://www-sciencedirect-com.translate.goog/science/article/pii/S2090123224002510?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

Zhao, L., Gao, X., Zheng, Y., Wang, Z., Zhao, G., Ren, J., Zhang, J., Wu, J., Wu, B., & Chen, Y. (2021). Establishment of bovine expanded potential stem cells. *Proceedings of the National Academy of Sciences*, *118*(15), e2018505118. https://pmc.ncbi.nlm.nih.gov/articles/PMC8053967/pdf/pnas.202018505.pdf

Zheng, Y., Li, Y., Zhou, K., Li, T., VanDusen, N. J., & Hua, Y. (2024). Precise genome-editing in human diseases: mechanisms, strategies and applications. *Signal Transduction and Targeted Therapy*, *9*(1), 47. https://www.nature.com/articles/s41392-024-01750-2.pdf?error=cookies_not_supported&code=c1a45cf0-4c86-4b0e-9969-bbe22179496b

Zumwalt, M., & Reddy, A. P. (2020). Stem cells for treatment of musculoskeletal conditions-orthopaedic/sports medicine applications. *Biochimica et Biophysica Acta (BBA)-Molecular Basis of Disease*, *1866*(4), 165624. https://www-sciencedirect-com.translate.goog/science/article/pii/S0925443919303527?_x_tr_sl=en&_x_tr_tl=es&_x_tr_hl=es&_x_tr_pto=tc

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Research conception and design: LQL, JABB; data analysis and interpeetation: JABB; redaction of the manuscript: JABB, LQL, ZARH.

CONFLICT OF INTEREST STATEMENT

The authors state there are no conflicts of interest whatsoever.