Short Communication
Volume 18:05, 2024

Journal of Molecular and Genetic Medicine

ISSN: 1747-0862

Open Access

Transgenic Models in Biomedical Research Advancements and Applications

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Introduction

Transgenic models have revolutionized biomedical research, offering invaluable insights into gene function and disease mechanisms. This article provides a comprehensive review of advancements in transgenic technologies and their applications in various fields, including genetics, oncology, neurobiology, and regenerative medicine. By discussing recent developments such as CRISPR/Cas9 technology, and highlighting specific case studies, we aim to elucidate the impact of transgenic models on modern biomedical research and their potential for future innovations. Transgenic models, organisms that have been genetically modified to express foreign genes, have become fundamental tools in biomedical research. These models, which can be developed in various organisms, including mice, rats, zebrafish, and even plants, enable researchers to study gene function, disease progression, and the efficacy of therapeutic interventions. The advent of sophisticated genetic engineering techniques has facilitated the creation of increasingly precise transgenic models, thereby enhancing our understanding of complex biological processes. The purpose of this review is to provide an overview of the advancements in transgenic technologies, their applications in different biomedical fields, and the challenges that remain in this rapidly evolving area of research.

Historically, the creation of transgenic organisms relied on methods such as microinjection, electroporation, and viral vector-mediated gene transfer. These techniques often produced low efficiency rates and unpredictable integration sites, which could lead to variable expression levels and unintended effects. The most common model organism for these traditional techniques has been the mouse, primarily due to its genetic similarity to humans and its well-established genetic background. The introduction of CRISPR/Cas9 technology has marked a significant breakthrough in the field of genetic engineering. This technique allows for precise editing of the genome with high efficiency and specificity. Researchers can create knock-in or knock-out models by targeting specific genes, thereby facilitating the study of gene function and the development of disease models [1,2].

Description

Recent advancements in delivery systems have improved the efficiency of transgenic techniques. Methods such as nanoparticle-mediated delivery, liposome encapsulation, and adeno-associated virus (AAV) vectors have shown promise in enhancing the uptake of genetic material into target cells. These innovations contribute to more reliable and reproducible models for research. Transgenic models have a wide range of applications across various fields of biomedical research. Below, we explore several key areas where these models have made significant contributions. Transgenic models play a crucial role in understanding gene function and the genetic basis of diseases. For example, the creation of reporter gene constructs, which express a detectable marker in response to specific genetic signals, has enabled researchers to visualize gene expression patterns during development. Mouse models have been extensively used to study the role of specific genes in development. The knock-out of the gene Sonic Hedgehog (Shh) in mice revealed its essential role in embryonic development, including the formation of the central nervous system and limb development. Such findings have broad implications for understanding congenital disorders in humans [3].

Transgenic models are indispensable in cancer research, allowing for the investigation of tumorigenesis and the testing of potential therapies. By introducing oncogenes or knocking out tumor suppressor genes, researchers can mimic the genetic alterations observed in human cancers. Transgenic mice expressing an activated form of TGF-β in the mammary gland have provided insights into the role of this pathway in breast cancer. These models have demonstrated that TGF-β can promote both tumor progression and metastasis, highlighting its dual role as both a tumor suppressor and promoter, depending on the context. Transgenic models have advanced our understanding of neurodegenerative diseases such as Alzheimer's and Parkinson's disease. By expressing human genes associated with these disorders in model organisms, researchers can study the underlying mechanisms and test potential therapeutic strategies.

The APP/PS1 mouse model, which expresses mutated forms of the amyloid precursor protein and Presenilin 1 (PS1), is widely used in Alzheimer's research. This model exhibits key features of Alzheimer's disease, including amyloid plaque formation and cognitive decline, making it an essential tool for testing anti-amyloid therapies. Transgenic models are also pivotal in the field of regenerative medicine, where understanding the mechanisms of tissue repair and regeneration can lead to new therapeutic strategies. Researchers are using transgenic approaches to manipulate gene expression in stem cells, enhancing their regenerative potential. Zebrafish are unique in their ability to regenerate limbs, heart, and other organs. Transgenic zebrafish expressing fluorescent proteins have been instrumental in visualizing cellular processes during regeneration. Studies have identified key signaling pathways involved in tissue regeneration, paving the way for potential applications in human medicine [4,5].

Conclusion

Despite the significant advancements in transgenic technologies and their applications, several challenges and ethical considerations remain. While CRISPR/Cas9 technology offers precision, off-target effects can still occur. Identifying and minimizing these unintended modifications is critical to ensuring the reliability of transgenic models. Ongoing research is focused on developing more accurate genome editing techniques. The use of transgenic animals raises ethical concerns regarding animal welfare. Researchers must adhere to strict guidelines and regulations to ensure humane treatment. The development of alternative models, such as organoids and cell lines, is an area of active investigation to reduce reliance on animal models. The reproducibility of results obtained from transgenic models can be affected by factors such as genetic background, environmental conditions, and differences in experimental protocols. Establishing standardized protocols and reporting practices is essential to enhance the reliability of findings across studies.

Acknowledgement

None.

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Received: 13 August, 2024, Manuscript No. jmgm-24-152017; **Editor assigned:** 15 August, 2024, PreQC No. P-152017; **Reviewed:** 27 August, 2024, QC No. Q-152017; **Revised:** 02 September, 2024, Manuscript No. R-152017; **Published:** 09 September, 2024, DOI: 10.37421/1747-0862.2024.18.692

Conflict of Interest

None.

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How to cite this article: Gary, Dewidar. "Transgenic Models in Biomedical Research Advancements and Applications." *J Mol Genet Med* 18 (2024): 692.