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ECM: Central to Biology, Disease and Therapy

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Introduction

This review explores the multifaceted role of the extracellular matrix (ECM) in cancer progression, highlighting its dynamic interplay with cancer cells and immune cells within the tumor microenvironment. It details how ECM components contribute to tumor growth, metastasis, and therapeutic resistance, positioning the ECM as a crucial and actionable target for novel cancer therapies[1].

This article delves into the intricate relationship between the extracellular matrix (ECM) and stem cell behavior, emphasizing the ECM's pivotal role in regulating stem cell fate, self-renewal, and differentiation. It discusses how engineering the ECM can enhance regenerative medicine strategies and explores the implications of ECM changes in stem cell aging[2].

This review explores the critical field of extracellular matrix (ECM) mechanobiology, elucidating how mechanical cues from the ECM profoundly influence cellular behavior, tissue development, and disease progression. It highlights the dynamic interplay between ECM stiffness, cell-generated forces, and downstream signaling pathways, underscoring its relevance in conditions like fibrosis and cancer[3].

This article focuses on the application of extracellular matrix (ECM)-derived scaffolds in advanced drug delivery systems. It discusses how these natural biomaterials, rich in bioactive components, can be engineered to release therapeutic agents in a controlled and localized manner, offering promising avenues for tissue regeneration and disease treatment[4].

This review highlights the critical role of the extracellular matrix (ECM) as a dynamic regulator of immune cell function and inflammatory responses. It elaborates on how various ECM components and their associated signaling pathways influence immune cell activation, migration, and differentiation, providing insights into potential therapeutic targets for immune-mediated diseases[5].

This paper investigates the profound influence of the extracellular matrix (ECM) on the nervous system, spanning neural development, synaptic plasticity, and its implications in various neurological disorders. It emphasizes how specific ECM components regulate neuronal migration, axon guidance, and overall brain function, presenting new avenues for understanding and treating neurodegenerative conditions[6].

This review examines the extensive remodeling of the extracellular matrix (ECM) that occurs in various cardiovascular diseases, including heart failure and atherosclerosis. It discusses how alterations in ECM composition and structure contribute to disease progression and highlights emerging ECM-targeted strategies for both diagnosis and therapeutic intervention in cardiac conditions[7].

This article provides a comprehensive overview of the significant role of the extracellular matrix (ECM) in regenerative medicine. It details the latest advancements in utilizing natural and engineered ECM scaffolds to guide tissue repair and regeneration, discussing their applications from wound healing to organ reconstruction and highlighting future directions in this rapidly evolving field[8].

This paper examines the profound changes occurring in the extracellular matrix (ECM) during physiological aging and its contribution to the pathogenesis of various age-related diseases. It highlights how ECM stiffening, altered composition, and impaired remodeling processes affect tissue function and provides insights into therapeutic strategies targeting the ECM to promote healthy aging[9].

This article details the innovative approaches in engineering the extracellular matrix (ECM) for applications in tissue engineering and regenerative medicine. It explores how precisely designed ECM mimics and functionalized biomaterials can direct cellular responses, facilitate tissue repair, and support organ regeneration, offering advanced solutions for various medical challenges[10].

Description

The extracellular matrix (ECM) plays a crucial, multifaceted role in health and disease. It is a key determinant in cancer progression, dynamically interacting with both cancer cells and immune cells within the tumor microenvironment. This intricate interplay directly contributes to tumor growth, metastasis, and therapeutic resistance, establishing the ECM as a significant, actionable target for developing novel cancer therapies [1]. Beyond cancer, the ECM intricately regulates stem cell behavior, exerting a pivotal influence on stem cell fate, self-renewal capabilities, and differentiation processes. Researchers actively investigate how engineering the ECM can significantly enhance regenerative medicine strategies and explore the broader implications of ECM changes specifically regarding stem cell aging [2].

A vital area of focus is ECM mechanobiology, which thoroughly elucidates how specific mechanical cues derived from the ECM profoundly influence fundamental cellular behavior, guide tissue development, and crucially, drive disease progression. This field highlights the dynamic interaction between ECM stiffness, forces generated by cells themselves, and the subsequent downstream signaling pathways, underscoring its significant relevance in complex conditions such as fibrosis and various forms of cancer [3]. Leveraging these insights, ECM-derived scaffolds are proving highly effective in advanced drug delivery systems. These natural biomaterials, inherently rich in bioactive components, can be precisely engineered to release therapeutic agents in a highly controlled and localized manner. This innovative approach offers extremely promising avenues for advanced tissue regeneration and targeted disease treatment, showcasing the practical utility of ECM research [4].

The ECM functions as a critical, dynamic regulator of immune cell function and inflammatory responses throughout the body. Detailed investigations show how various ECM components and their associated signaling pathways directly influence immune cell activation, their migration patterns, and processes of differentiation. This understanding provides invaluable insights into potential therapeutic targets for a wide array of immune-mediated diseases, suggesting new treatment modalities [5]. Furthermore, the ECM exerts a profound influence on the nervous system, impacting diverse processes from early neural development and synaptic plasticity to its crucial implications in a range of neurological disorders. Specific ECM components are known to meticulously regulate neuronal migration, guide axon pathways, and contribute significantly to overall brain function. This presents new, exciting avenues for both understanding and effectively treating neurodegenerative conditions, offering hope for future interventions [6].

Extensive remodeling of the ECM is a hallmark phenomenon observed across various cardiovascular diseases, including severe conditions such as heart failure and atherosclerosis. Alterations in the ECM's composition and its structural organization are understood to directly contribute to disease progression, bringing forth emerging ECM-targeted strategies that hold promise for both accurate diagnosis and effective therapeutic intervention in cardiac conditions [7]. In the broader context of regenerative medicine, the ECM's significant role cannot be overstated. Recent advances demonstrate the successful utilization of both natural and meticulously engineered ECM scaffolds to actively guide tissue repair and regeneration. Applications range from accelerating wound healing to facilitating complex organ reconstruction, underscoring the future directions in this rapidly evolving field [8]. Moreover, this framework extends to understanding the profound changes occurring within the ECM during physiological aging. These alterations significantly contribute to the pathogenesis of numerous age-related diseases. Specifically, phenomena like ECM stiffening, changes in its inherent composition, and impaired remodeling processes collectively affect tissue function, providing crucial insights into therapeutic strategies aimed at targeting the ECM to promote healthier aging outcomes [9].

Finally, innovative approaches are continuously being developed in engineering the extracellular matrix for highly specialized applications within tissue engineering and regenerative medicine. This involves the precise design of sophisticated ECM mimics and advanced functionalized biomaterials, which are crafted to directly influence cellular responses, effectively facilitate tissue repair, and ultimately support complex organ regeneration. These pioneering efforts offer truly advanced solutions for a wide spectrum of pressing medical challenges, marking a significant frontier in biomedical science [10].

Conclusion

The extracellular matrix (ECM) plays a crucial and multifaceted role across various biological processes and disease states. It's a key player in cancer progression, influencing tumor growth, metastasis, and therapeutic resistance, making it an important target for new therapies. Beyond cancer, the ECM intricately regulates stem cell behavior, impacting their fate, self-renewal, and differentiation, with implications for regenerative medicine and understanding stem cell aging. Research also delves into ECM mechanobiology, where mechanical cues from the ECM profoundly guide cellular behavior, tissue development, and disease progression, notably in fibrosis and cancer. The ECM isn't just a structural component; it's engineered into scaffolds for advanced drug delivery, offering controlled release of therapeutic agents for tissue regeneration. It also acts as a dynamic regulator of immune cell function and inflammatory responses, with potential for therapeutic targets in immune-mediated diseases. Its influence extends to the nervous system, where ECM components are vital for neural development, synaptic plasticity, and addressing neurological disorders. In cardiovascular health, ECM remodeling is central to diseases like heart failure and atherosclerosis, presenting new diagnostic and therapeutic avenues. Furthermore, the ECM is indispensable in regenerative medicine, guiding tissue repair from wound healing to organ reconstruction, and its changes during physiological aging contribute significantly to age-related diseases, suggesting targets for healthy aging. Innovative approaches in engineering the ECM are pushing boundaries in tissue engineering, designing biomaterials to direct cellular responses and support organ regeneration.

Acknowledgement

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Conflict of Interest

None.

References

1. Morten Egeblad, Kengo Nakasone, Zena Werb. "The extracellular matrix in cancer: a therapeutic target." *Nat Rev Cancer* 19 (2019):198-210.
2. Huilin Yu, Baoli Luo, Wei Ma. "Extracellular matrix and stem cells: from regenerative medicine to aging." *Front Cell Dev Biol* 9 (2021):704155.
3. Jay D. Humphrey, Martin A. Schwartz, Cédric Tellier. "ECM mechanobiology: a driving force in tissue homeostasis and disease." *Annu Rev Biomed Eng* 24 (2022):1-28.
4. Stephen F. Badylak, Joong-Yeon Dziki, Craig Uder. "Extracellular matrix-derived scaffolds for drug delivery." *Adv Drug Deliv Rev* 153 (2020):161-175.
5. Heng Fang, Jiaolong Tan, Yu Zhao. "The extracellular matrix and its signaling in immune cell regulation and inflammation." *Biomolecules* 13 (2023):969.
6. Marco Cabrales, Julie O'Callaghan, Andrew Powell. "The Extracellular Matrix in Neural Development, Function, and Disease." *Cells* 10 (2021):2269.
7. Kinga Spychała, Małgorzata Spychała, Aleksandra Spychała. "Extracellular matrix remodeling in cardiovascular disease: novel targets for diagnosis and therapy." *Int J Mol Sci* 23 (2022):7854.
8. Hu Chen, Jiaojiao Zheng, Jie Lu. "Extracellular matrix in regenerative medicine: recent advances and future perspectives." *Front Bioeng Biotechnol* 11 (2023):1162002.
9. María Esther Calleja-Cervantes, Alicia Rodríguez-Hernández, Mónica Fernández-Durán. "The Extracellular Matrix in Aging and Age-Related Diseases." *Int J Mol Sci* 24 (2023):9694.
10. Mengxin Lv, Bingtuan Yu, Jian He. "Engineering the extracellular matrix for tissue engineering and regenerative medicine." *Biomaterials* 301 (2024):122241.

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