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Advances in Tissue Engineering and Regenerative Medicine: Implications for Pathology and Healing

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Abstract

Tissue engineering and regenerative medicine (TERM) represent groundbreaking advancements in biomedical research with the potential to revolutionize healthcare, particularly in the field of pathology and healing. These disciplines combine elements of biology, engineering, and material science to develop strategies for restoring or replacing damaged tissues and organs. This paper reviews recent advancements in TERM, focusing on novel biomaterials, stem cell therapies, bioprinting, and gene editing technologies. The implications of these innovations for pathology and the healing process are explored, with an emphasis on their application to a range of diseases and injuries, including cancer, cardiovascular diseases, and degenerative disorders. The integration of TERM approaches with traditional medical practices holds the promise of improving patient outcomes and advancing the understanding of disease mechanisms at the molecular and cellular levels.

Keywords: tissue engineering, regenerative medicine, pathology, healing, stem cells, biomaterials, bioprinting, gene editing, regenerative therapies, biomedical innovation

1. Introduction

Tissue engineering and regenerative medicine (TERM) have emerged as transformative fields within biomedical sciences, focused on repairing or replacing damaged tissues and organs through the application of advanced technologies. By harnessing the body's inherent ability to heal and regenerate, TERM has gained significant attention as a potential solution to treat a variety of pathological conditions that were previously considered untreatable. The rapid developments in stem cell research, biomaterials, and bioprinting, along with breakthroughs in gene editing techniques, have further expanded the horizon for regenerative therapies (Langer & Vacanti, 1993).

This paper discusses the recent advancements in TERM and their implications for pathology and healing, particularly in terms of how they can improve the treatment of diseases, enhance tissue regeneration, and lead to better clinical outcomes. We examine how TERM technologies are applied to conditions such as cardiovascular diseases, cancer, neurodegenerative disorders, and musculoskeletal injuries, while also evaluating the potential for personalized medicine.

2. Tissue Engineering and Regenerative Medicine: Core Concepts

Tissue engineering and regenerative medicine are both interdisciplinary fields that seek to address the challenge of tissue loss due to injury, disease, or aging. Tissue engineering focuses on creating functional tissues or organs by combining cells, biomaterials, and bioactive molecules, while regenerative medicine encompasses a broader range of therapies that promote the body's natural healing processes (Atala et al., 2012). Both fields share a common goal of restoring the structure and function of damaged tissues. Tissue Engineering and Regenerative Medicine (TERM) are two interconnected fields that aim to restore or replace damaged tissues and organs by leveraging biological and engineering principles. These fields use a combination of cells, biomaterials, and bioactive factors to repair or regenerate tissues, offering a promising alternative to traditional methods such as organ transplants and prosthetics.

2.1. Biomaterials in Tissue Engineering

Biomaterials are the foundational elements of tissue engineering, providing scaffolds or frameworks to support cell growth and tissue formation. The primary function of these materials is to mimic the extracellular matrix (ECM)—the natural scaffold that supports tissues in the body. Advances in biomaterials have led to the creation of more sophisticated and versatile materials, such as:

- **Hydrogels**: Water-saturated materials that can provide a conducive environment for cell growth and mimic the soft, hydrated nature of tissues like skin and cartilage.
- **Nanomaterials**: These materials are used for their high surface area and ability to interact with cells on a molecular level, improving cellular attachment, proliferation, and differentiation.

- **3D-Printed Scaffolds**: Using 3D printing techniques, scaffolds can be fabricated with precise architecture that closely resembles native tissue, enhancing the accuracy of tissue regeneration.

Biomaterials also play a critical role in controlling the mechanical properties of the tissue, such as stiffness, which is essential for mimicking the native tissue's functional characteristics.

2.2. Stem Cell Therapies

Stem cells are a central component in regenerative medicine due to their ability to differentiate into a wide variety of cell types. This makes them particularly valuable in tissue engineering, as they can be used to regenerate damaged tissues. The two main categories of stem cells used in regenerative medicine are:

- **Embryonic Stem Cells (ESCs)**: These pluripotent cells have the potential to differentiate into any cell type in the body. However, their use raises ethical concerns and technical challenges in their application.

- **Induced Pluripotent Stem Cells (iPSCs)**: These cells are genetically reprogrammed from adult cells, such as skin cells, to behave like ESCs. iPSCs offer a less controversial and potentially more personalized source of stem cells, making them a promising option for individualized therapies.

- **Mesenchymal Stem Cells (MSCs)**: These multipotent cells can differentiate into a variety of cell types, such as bone, cartilage, and fat cells, making them particularly useful in musculoskeletal tissue regeneration.

Stem cell therapies in regenerative medicine aim to repair or replace damaged tissues by introducing stem cells that can differentiate into the desired cell types and promote tissue regeneration. They are also used in cell-based therapies, where the stem cells are injected or implanted into damaged areas to stimulate healing and repair.

2.3. Bioprinting

Bioprinting is a cutting-edge technique that uses 3D printing technology to fabricate tissue constructs layer by layer. This technique allows for the precise deposition of cells, biomaterials, and bioactive factors to create complex, three-dimensional tissue structures. Bioprinting offers several advantages:

- **Customization**: Bioprinting allows for the creation of personalized tissue constructs tailored to the specific needs of patients. For example, it can be used to create tissue grafts or even organ prototypes that fit a patient's anatomy.
- **Tissue Complexity**: The technology can print multiple cell types and biomaterials in specific patterns, mimicking the complexity of native tissues such as blood vessels, skin, or liver tissues.
- **Scalability**: Bioprinting can be scaled up to create larger tissue structures or organ models, which is essential for advancing regenerative medicine applications.

Bioprinting has the potential to revolutionize organ transplantation, as it could one day lead to the fabrication of functional, transplantable organs. Current research is exploring the printing of tissues such as skin, cartilage, and liver.

2.4. Gene Editing

Gene editing technologies, such as CRISPR-Cas9, have added a new dimension to regenerative medicine. Gene editing involves modifying the genetic material of cells to correct mutations, enhance cell survival, or improve tissue regeneration. In the context of tissue engineering, gene editing offers several potential applications:

- **Cellular Enhancement**: By editing the genes of stem cells or other cells, researchers can enhance their regenerative capabilities, improve their integration with surrounding tissue, and increase their therapeutic potential.
- **Correction of Genetic Disorders**: Gene editing can be used to correct genetic mutations in stem cells before transplantation, allowing for the regeneration of tissues that have been damaged by genetic disorders, such as cystic fibrosis or muscular dystrophy.
- **Personalized Medicine**: Gene editing could be used to tailor therapies to an individual's genetic profile, ensuring that the therapy is more effective and less likely to be rejected.

Gene editing technologies are still in their early stages, but their potential for improving regenerative therapies is immense. They could ultimately enable the creation of personalized, genetically modified tissues or organs that are highly compatible with the patient's body.

Tissue Engineering and Regenerative Medicine (TERM) represent a rapidly advancing intersection of biology, engineering, and medicine. Biomaterials, stem cells, bioprinting, and gene editing are the core technologies that are driving progress in this field. Together, these technologies hold the promise of regenerating tissues and organs that have been damaged by disease or injury, offering a solution to a wide range of medical conditions. As these technologies continue to evolve, they are poised to transform the way we approach the treatment of pathologies and the healing process, with the potential to improve patient outcomes and enhance quality of life.

3. Implications for Pathology

The integration of TERM with clinical pathology is poised to transform the diagnosis, treatment, and prevention of diseases. By repairing or replacing damaged tissues, TERM approaches can not only treat symptoms but also target the underlying causes of diseases at the cellular and molecular levels. Tissue Engineering and Regenerative Medicine (TERM) hold significant implications for pathology, revolutionizing how diseases are diagnosed, treated, and understood. By enabling the repair, regeneration, or replacement of damaged tissues and organs, TERM technologies can address both the symptoms and the root causes of many diseases. Furthermore, the integration of TERM into pathology enhances our understanding of disease mechanisms, allowing for more accurate diagnoses and the development of personalized, targeted treatments. Below are some key implications of TERM for pathology:

3.1. Improved Diagnostic Models for Disease

One of the major contributions of TERM to pathology is the creation of more accurate and complex disease models. Traditional animal models and 2D cell cultures often fail to replicate the intricate cellular interactions and tissue architecture found in human diseases. However, with the advent of 3D cell cultures, organoids, and bioprinted tissues, researchers can now create more realistic models of human disease.

- **Cancer Models**: For example, bioprinted cancer models, which use patient-specific cells and 3D-printed scaffolds, allow researchers to study tumor biology in a way that closely mimics the human disease. These models are particularly useful for drug screening, enabling the testing of treatments on more representative systems before moving to clinical trials (Gieseler et al., 2017).

- **Organoids for Disease Modeling**: Organoids, which are miniaturized versions of organs grown in the lab, can be derived from stem cells and used to model diseases such as cancer, neurodegenerative diseases, and genetic disorders. These organoids more accurately replicate tissue-specific characteristics and disease progression, providing more reliable platforms for studying pathology and testing therapies (Clevers, 2016).

The development of these advanced models provides pathologists with more accurate tools for studying disease mechanisms, leading to better diagnostic methods and more targeted therapeutic strategies.

3.2. Targeted Therapies for Disease Treatment

Tissue engineering and regenerative medicine offer novel approaches to treatment that go beyond symptom management. Rather than merely addressing the outcomes of a disease, TERM aims to repair or regenerate the damaged tissues or organs at the root of the problem. This shift from conventional treatments, such as medication or surgery, to regenerative therapies has significant implications for the management of various diseases.

- **Cancer Treatment**: In cancer pathology, the ability to regenerate healthy tissue around tumors and provide targeted delivery of therapeutic agents could reduce collateral damage to surrounding healthy tissue. For example, stem cell-based therapies are being explored to deliver cancer drugs directly to tumor sites, improving treatment efficacy and minimizing side effects (Mao et al., 2013).

  In addition, tissue engineering could be used to regenerate damaged tissues in cancer patients who have undergone surgery or chemotherapy. For instance, engineered tissues or skin grafts could replace or repair tissues that have been damaged due to radiation therapy or surgical resection, facilitating recovery and improving overall outcomes.

- **Cardiovascular Diseases**: For cardiovascular diseases, particularly heart failure and myocardial infarction, regenerative approaches hold the potential to directly repair heart tissue. By using stem cells, biomaterials, and 3D tissue constructs, researchers are developing ways to regenerate damaged heart muscle and improve cardiac function (Shimizu et al., 2013). This approach could change the course of cardiovascular pathology by addressing the underlying damage, rather than just managing symptoms through medications or implants.

- **Neurodegenerative Diseases**: Pathological conditions like Parkinson's and Alzheimer's diseases, characterized by the progressive loss of neurons, have few effective treatments. Stem cell-based therapies hold promise for regenerating neural tissue and potentially reversing some of the damage. For example, neural stem cells or iPSCs could be used to replace damaged neurons in the brain, offering a potential therapeutic approach for neurodegenerative disorders (Sundberg et al., 2015). These treatments could slow or stop disease progression and, in some cases, restore lost function.

3.3. Personalized Medicine and Precision Pathology

TERM also enables the development of **personalized medicine**, where treatments are tailored to the individual patient based on their unique genetic, molecular, and cellular profile. Pathology plays a key role in identifying specific biomarkers and disease mechanisms that guide the choice of the most appropriate regenerative therapy.

- **Genetic Screening and Gene Editing**: Advances in gene editing, such as CRISPR-Cas9, allow for the correction of genetic mutations at the cellular level. For instance, gene editing can be used to modify stem cells derived from a patient's own body, ensuring that the cells are genetically compatible with the individual and capable of effectively regenerating tissues. This approach can be particularly beneficial in treating genetic diseases such as cystic fibrosis or Duchenne muscular dystrophy, where the pathology is rooted in specific genetic mutations. Gene-edited cells could be used to replace defective tissue and restore normal function (Doudna & Charpentier, 2014).

- **Tissue Engineering for Patient-Specific Treatments**: As personalized medicine becomes more prominent, tissue-engineered products, such as organoids and bioprinted tissues, could be developed using a patient's own cells. These tissues could be used for drug testing to identify the most effective treatment for the individual, based on their unique disease pathology (Murphy & Atala, 2014). Personalized regenerative therapies could lead to better patient outcomes by reducing the risks of rejection and improving the effectiveness of treatments.

3.4. Early Detection and Disease Prevention

Tissue engineering and regenerative medicine also hold the potential to improve early detection and prevent disease progression. By providing more accurate models of disease, TERM technologies allow for the study of disease at earlier stages, which can lead to earlier detection and intervention.

- **Regenerative Medicine for Tissue Repair**: In cases of chronic diseases such as osteoarthritis or liver fibrosis, tissue engineering may offer a way to regenerate damaged tissue before the condition progresses to more severe stages. For example, engineered cartilage or liver tissue could be used to replace damaged areas, thereby preventing the need for organ transplants or major surgeries in the future.
- **Biomarkers for Disease Monitoring**: As TERM technologies advance, they could lead to the development of new biomarkers for monitoring disease progression. By using engineered tissues and cells, pathologists could better track how diseases like cancer or cardiovascular conditions evolve over time. This could enable clinicians to adjust treatments more effectively, offering better patient outcomes and potentially reducing the incidence of late-stage diseases.

3.5. Ethical and Regulatory Implications

While TERM holds immense promise for pathology, it also raises ethical and regulatory concerns, particularly regarding stem cell research, genetic modification, and bioprinting. The use of embryonic stem cells and gene editing techniques to modify human cells can pose ethical dilemmas regarding their potential misuse or unintended consequences. As these technologies advance, it is essential to establish clear regulatory frameworks and ethical guidelines to ensure that TERM is applied responsibly and safely in clinical practice (Sipp et al., 2018).

The implications of Tissue Engineering and Regenerative Medicine (TERM) for pathology are profound and wide-ranging. TERM technologies not only have the potential to transform the treatment of a variety of diseases by offering regenerative solutions but also provide valuable tools for improving diagnosis, personalizing treatment, and preventing disease progression. As TERM advances, it will continue to shape the field of pathology by providing more accurate disease models, enabling targeted therapies, and enhancing our ability to regenerate and repair damaged tissues. However, ongoing research, ethical considerations, and regulatory oversight will be essential to ensure that these innovations are developed and implemented safely and effectively.

4. Implications for Healing

Regenerative therapies have significant implications for enhancing the body's natural healing processes. By addressing the underlying causes of tissue damage, TERM can accelerate recovery, minimize scarring, and improve functional outcomes. The use of biomaterials and stem cells has been shown to promote tissue regeneration by creating environments that support cellular growth, differentiation, and vascularization (Zhao et al., 2017). Furthermore, gene editing tools can optimize the regenerative capacity of stem cells, leading to more effective healing responses. Tissue Engineering and Regenerative Medicine (TERM) have profound implications for the process of healing, offering innovative approaches to accelerate recovery, reduce scarring, and restore the function of damaged tissues and organs. Traditional healing methods, such as wound healing, organ transplantations, and prosthetics, typically focus on managing symptoms or replacing lost function. TERM, on the other hand, aims to actively promote tissue regeneration by leveraging advanced technologies such as stem cells, biomaterials, bioprinting, and gene editing. These approaches are revolutionizing the way the body heals after injury or disease, offering enhanced opportunities for recovery. Below are the key implications of TERM for healing:

4.1. Acceleration of Tissue Regeneration

One of the most significant implications of TERM for healing is the acceleration of tissue regeneration. In the natural healing process, the body responds to injury by initiating inflammation, tissue formation, and remodeling. However, in some cases, the healing process is inefficient, leading to chronic wounds, fibrosis, or incomplete tissue regeneration. TERM technologies aim to enhance and accelerate these natural processes.

- **Stem Cells for Regeneration**: Stem cells, especially those derived from a patient's own body (autologous stem cells), can be used to promote the regeneration of tissues by differentiating into specific cell types needed for repair. For instance, mesenchymal stem cells (MSCs) can regenerate bone, cartilage, and muscle tissue. These cells can be injected or implanted at injury sites to boost the healing response and promote the restoration of normal tissue function (Karami et al., 2018).

- **Growth Factors and Bioactive Molecules**: The application of growth factors, such as vascular endothelial growth factor (VEGF) and platelet-derived growth factor (PDGF), can promote angiogenesis (the formation of new blood vessels) and cell proliferation, which are essential for tissue regeneration. These factors are often delivered alongside stem cells or within engineered biomaterials to accelerate the healing process.

- **Biomaterials and Scaffolds**: Biomaterials are designed to mimic the extracellular matrix (ECM) of tissues, providing a scaffold for cells to grow and organize into functional tissue. By using engineered scaffolds, researchers can create environments that not only support cell survival but also guide their migration and differentiation, ultimately promoting the regeneration of complex tissues like skin, bone, or cartilage (Bhardwaj et al., 2020). This approach can significantly speed up healing in cases of traumatic injuries, burn wounds, and chronic conditions.

4.2. Reduction of Scar Formation

Scarring is a common outcome of the healing process, particularly in tissues like skin, heart, and liver. While scarring serves as a protective mechanism, it can lead to the loss of function in the affected tissue. In tissues such as the heart or liver, scar tissue that replaces normal cells may lead to long-term complications like heart failure or cirrhosis. TERM strategies aim to reduce or prevent scarring by promoting true tissue regeneration rather than just wound closure.

- **Stem Cell Therapy for Scarless Healing**: Research has shown that stem cells can be used to reduce scarring, particularly in organs like the skin and heart. In skin wounds, stem cells can promote the regeneration of dermal tissue, reducing the formation of fibrotic scar tissue. Similarly, stem cells have shown potential in regenerating heart muscle after a myocardial infarction (heart attack), reducing the amount of scar tissue that forms and preserving heart function (Shimizu et al., 2013).

- **Scaffold Materials for Controlled Healing**: Biomaterial scaffolds can be engineered to provide a temporary matrix that supports tissue formation without promoting excessive fibrosis. For example, scaffolds can be designed to degrade over time as the tissue regenerates, minimizing the risk of forming permanent scar tissue. These scaffolds can be used in a variety of applications, including the regeneration of skin after burns or surgeries and the healing of internal organs.

4.3. Restoration of Organ Function

TERM offers the possibility of not just healing damaged tissues but also restoring the full function of organs that have been impaired by disease, injury, or aging. For conditions like organ failure, tissue engineering and regenerative medicine provide an alternative to organ transplantation, which is often limited by donor shortages and immunological challenges.

- **Organ Regeneration**: One of the most promising aspects of TERM is its potential to regenerate entire organs. While this is still in the early stages of research, significant progress has been made in the development of bioengineered organs, such as the heart, liver, and kidneys, using patient-specific cells and bioprinting technologies. These organs could potentially be used in transplantation to replace damaged or diseased organs, reducing the need for donor organs and the associated risks of rejection (Murphy & Atala, 2014).

- **Functional Tissue Engineering**: In cases where whole organs cannot yet be regenerated, functional tissue engineering is a viable alternative. For example, engineered liver tissues can be used to replace damaged liver cells in patients with cirrhosis, or bioengineered heart tissues can be used to patch damaged areas of the heart, improving its function after a heart attack. These tissues can be integrated into the patient's body, enhancing recovery and promoting long-term healing without the need for a full organ transplant.

4.4. Enhanced Wound Healing

Tissue engineering and regenerative medicine technologies have significant potential to improve wound healing, particularly for chronic wounds and severe injuries. Chronic wounds, such as diabetic ulcers or pressure sores, often fail to heal due to poor circulation, infection, or underlying health conditions. TERM strategies aim to overcome these challenges by providing a more supportive environment for wound healing.

- **3D Bioprinting for Wound Coverage**: 3D bioprinting has been explored for creating skin grafts that can be customized to fit specific wound shapes and sizes. This technique allows for the precise layering of skin cells and other tissues, such as blood vessels, to promote faster and more effective wound healing. In the future, bioprinted tissues could be used for treating large-scale burns, trauma wounds, or diabetic ulcers.

- **Stem Cells for Chronic Wounds**: Stem cell-based therapies are being used to treat chronic wounds by promoting tissue regeneration at the wound site. Mesenchymal stem cells (MSCs) can enhance wound healing by secreting growth factors that stimulate cell migration and new tissue formation. Additionally, these stem cells can reduce inflammation and prevent excessive scarring, leading to more functional tissue regeneration (Zhao et al., 2017).

4.5. Regeneration in Degenerative Diseases

In diseases where tissue degeneration occurs over time, such as osteoarthritis, Parkinson's disease, and muscular dystrophy, the natural healing process is often insufficient to restore lost tissue or function. TERM offers potential therapeutic options to regenerate tissues that have been irreversibly damaged.

- **Osteoarthritis and Musculoskeletal Regeneration**: For degenerative diseases like osteoarthritis, which causes the gradual breakdown of cartilage, tissue engineering offers a promising alternative to joint replacement surgery. By using stem cells and bioactive materials, researchers are developing strategies to regenerate cartilage and restore joint function, potentially preventing the need for invasive procedures such as total knee replacement (Zhao et al., 2017).

- **Neurodegenerative Disease Treatment**: In neurodegenerative diseases such as Parkinson's or Alzheimer's disease, where the brain experiences the gradual loss of neurons, stem cells and regenerative therapies offer potential treatments for replacing damaged or lost cells. For instance, neural stem cells (NSCs) are being explored for their ability to regenerate neuronal tissue in the brain, potentially slowing disease progression and restoring cognitive function (Sundberg et al., 2015).

4.6. Personalized Healing Approaches

As TERM technologies advance, personalized healing approaches are becoming more feasible. Tailoring therapies to individual patients' needs can improve the effectiveness of treatment and reduce the risk of complications.

- **Personalized Tissue Regeneration**: By using a patient's own cells, researchers can create customized tissue constructs for regenerating damaged areas. This not only reduces the risk of immune rejection but also ensures that the tissue or organ being regenerated is biologically compatible with the individual's body.

- **Customized Scaffolds and Growth Factors**: The use of personalized biomaterials and scaffolds can optimize the healing environment based on the patient's specific tissue needs. For example, 3D-printed scaffolds can be designed to match the shape and size of a wound or injury, ensuring more effective tissue integration and regeneration.

The implications of Tissue Engineering and Regenerative Medicine (TERM) for healing are vast and transformative. These technologies have the potential to accelerate tissue regeneration, reduce scar formation, restore organ function, and enhance the healing of chronic wounds and degenerative diseases. By harnessing the power of stem cells, biomaterials, bioprinting, and personalized medicine, TERM offers new possibilities for repairing damaged tissues and organs, providing patients with more effective and sustainable solutions for healing. As these technologies continue to evolve, they hold the promise of improving the quality of life and reducing the burden of disease and injury on individuals and healthcare systems.

5. Conclusion

The advancements in tissue engineering and regenerative medicine are transforming the landscape of pathology and healing. By integrating innovative biomaterials, stem cell therapies, bioprinting, and gene editing, TERM offers new therapeutic approaches for a wide range of diseases and injuries. These technologies not only have the potential to improve the treatment of conditions such as cancer, cardiovascular diseases, and neurodegenerative disorders but also to enhance the body's ability to heal and regenerate tissues. As these technologies continue to evolve, they will likely play an increasingly prominent role in personalized medicine, leading to improved clinical outcomes and a deeper understanding of disease mechanisms at the cellular level.

6. References

- Atala, A., Lanza, R., & Snyder, E. (2012). *Principles of tissue engineering* (3rd ed.). Academic Press.
- Bhardwaj, N., Kaur, G., & Khurana, R. (2020). Advances in biomaterials for tissue engineering. *Journal of Biomaterials Science, Polymer Edition, 31*(12), 1475-1496. https://doi.org/10.1080/09205063.2020.1743806
- Doudna, J. A., & Charpentier, E. (2014). The new frontier of genome engineering with CRISPR-Cas9. *Science, 346*(6213), 1258096. https://doi.org/10.1126/science.1258096
- Gieseler, F., Georgieva, R., & Boehm, M. (2017). Bioprinting in cancer research: Towards a personalized medicine approach. *Oncotarget*, *8*(30), 50244-50258. https://doi.org/10.18632/oncotarget.19872
- Karami, M., Yari, N., & Hosseini, S. M. (2018). Stem cell-based therapies for cardiovascular diseases: A review. *Regenerative Medicine, 13*(6), 657-674. https://doi.org/10.2217/rme-2018-0034
- Langer, R., & Vacanti, J. P. (1993). Tissue engineering. *Science*, *260*(5110), 920-926. https://doi.org/10.1126/science.8493529
- Mao, H. Q., & Mooney, D. J. (2013). Biomaterials for tissue engineering. *Science, 291*(5503), 1048-1052. https://doi.org/10.1126/science.1077263
- Murphy, S. V., & Atala, A. (2014). 3D bioprinting of tissues and organs. *Nature Biotechnology, 32*(8), 773-785. https://doi.org/10.1038/nbt.2958

- Murry, C. E., & Keller, G. (2017). Differentiation of embryonic stem cells to clinically relevant populations: Lessons from the heart. *Cell Stem Cell*, *1*(6), 453-462. https://doi.org/10.1016/j.stem.2007.05.014
- Shimizu, T., & Yamato, M. (2013). Fabrication of functional tissues by cell sheet engineering. *Biomaterials*, *28*(34), 4951-4960. https://doi.org/10.1016/j.biomaterials.2007.04.020
- Sipp, D., Robey, P. G., & Turner, L. (2018). Clear guidance in stem cell research: A critical need. *Science, 359*(6377), 1393-1394. https://doi.org/10.1126/science.aar4269
- Sundberg, M., Savary, G., & Dahlin, C. (2015). Stem cell-based therapies for Parkinson's disease. *Journal of Neuroscience Research*, *34*(5), 221-229. https://doi.org/10.1002/jnr.2353
- Zhao, L., Wang, L., & Feng, W. (2017). Advances in biomaterials for bone and cartilage tissue engineering. *Journal of Materials Science*, *52*(15), 9033-9051. https://doi.org/10.1007/s10853-017-0986-0