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14th International Conference on Nanomaterials and Nanotechnology, March 30-31, 2017 | Madrid, Spain-Advancing biomaterials of human origin for tissue engineering

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Biomaterials have played an increasingly prominent role in the success of biomedical devices and in the development of tissue engineering, which seeks to unlock the regenerative potential innate to human tissues/organs in a state of deterioration and to restore or reestablish normal bodily function. Advances in our understanding of regenerative biomaterials and their roles in new tissue formation can potentially open a new frontier in the fast-growing field of regenerative medicine. Taking inspiration from the role and multi-component construction of native extracellular matrices (ECMs) for cell accommodation, the synthetic biomaterials produced today routinely incorporate biologically active components to define an artificial in vivo milieu with complex and dynamic interactions that foster and regulate stem cells, similar to the events occurring in a natural cellular microenvironment. The range and degree of biomaterial sophistication have also dramatically increased as more knowledge has accumulated through materials science, matrix biology and tissue engineering. However, achieving clinical translation and commercial success requires regenerative biomaterials to be not only efficacious and safe but also cost-effective and convenient for use and production. Utilizing biomaterials of human origin as building blocks for therapeutic purposes has provided a facilitated approach that closely mimics the critical aspects of natural tissue with regard to its physical and chemical properties for the orchestration of wound healing and tissue regeneration. In addition to directly using tissue transfers and transplants for repair, new applications of human-derived biomaterials are now focusing on the use of naturally occurring biomacromolecules, decellularized ECM scaffolds and autologous preparations rich in growth factors/non-expanded stem cells to either target acceleration/magnification of the body's own repair capacity or use nature's paradigms to create new tissues for restoration. In particular, there is increasing interest in separating ECMs into simplified functional domains and/or biopolymeric assemblies so that these components/constituents can be discretely exploited and manipulated for the production of bioscaffolds and new biomimetic biomaterials. Here, following an overview of tissue auto-/allo-transplantation, we discuss the recent trends and advances as well as the challenges and future directions in the evolution and application of human-derived biomaterials for reconstructive surgery and tissue engineering. In particular, we focus on an exploration of the structural, mechanical, biochemical and biological information present in native human tissue for bioengineering applications and to provide inspiration for the design of future biomaterials. The human body has a limited ability to correctly auto-regenerate most, if not all, of its major tissues and organs in the event that the original tissue integrity has been seriously damaged as a result of medical disorders involving tissue dysfunction or devastating deficits. Faced with an ever-increasing burden of trauma, congenital abnormalities and degenerative diseases, tissue engineering and regenerative medicine promise to develop new biological therapeutics to treat a diverse range of diseases that are currently intractable. Additionally, in most cases, this type of research seeks to assist and accelerate the regenerative process by stimulating the patient's own inherent healing potential or, alternatively, to

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create replacement biological tissues (or, more challengingly, whole organs) to replace damaged, deteriorated or lost body parts. These therapeutic strategies regulate physiological conditions in a spatial and temporal manner and mimic the mechanisms of normal tissue repair and regeneration in different parts of the human body, and endeavors in this field have sparked a revolution in current and emerging trends in medical science.

Although bold steps have been made toward creating tissue constructs that could serve as integral parts of the clinical toolbox, many of these engineered tissues fail to fully match the functional properties of their native counterparts. This failure is partially due to our poor quantitative understanding of the mechanisms of the adaptive responses (i.e., the growth and remodeling processes) that modify the architecture of engineered tissues following in vivo transplantation. Considering that most living tissues are composed of numerous repeating units that are hierarchically assembled across multiple length scales and possess well-defined three-dimensional (3D) microarchitectural features and tissue-specific functional properties, the production of micron-sized tissue modules has attracted increasing interest in the fast-growing field of tissue engineering. These modules can be used alone as living materials (fillers) to repair wounded tissues at the sites of injury or can serve as building blocks for the generation of large tissue grafts or whole-organ implants through a so-called “bottom-up” approach. In light of these applications, in vitro, it is indispensable to recapitulate not only the structural organization but also the cellular and molecular composition of a native tissue to enhance the biological performance and the overall therapeutic outcome of such engineered tissues upon in vivo transplantation. Such modular tissues could be extraordinarily useful when used as injectable living microtissues for repair at sites of injury. Alternatively, if assembled into large 3D tissues, these modules could also be used as a patch for a large number of types of hitherto intractable extended damage to restore tissue function. In the future, an increased availability of engineered “living” tissue or organ substitutes could significantly reduce the demand for organ replacement and dramatically expedite the development of new therapeutics that can cure patients with revivable organ failure, eliminating the need for organ all transplantation altogether. These cells are normally transplanted within a biomaterial-cell construct based on a biodegradable 3D matrix that provides the requisite extracellular milieu, which contains physical and chemical cues for cell-driven tissue development and regeneration. Although a wide variety of therapeutic strategies based on different types of biomaterials and stem cells have been and are still being explored, in practice, modern tissue engineering is not an easily accessible approach to achieve regeneration in a clinical setting. In particular, several biological (e.g., a poor understanding of underlying mechanisms), technical (e.g., the large-scale expansion of stem cells) and regulatory (e.g., cost and safety) hurdles relating to the use of exogenously manipulated stem cells and engineered constructs for human therapeutics have yet to be overcome. In addition, a thorough understanding of the normal physiological processes in tissue development and of the mechanisms underlying the interactions between stem cells and biomaterials during the cascade of new tissue formation will be required to advance this field, as many crucial details remain unclear. Broadly speaking, biomaterials can be defined as material devices or implants used to repair/replace native body tissues or as scaffolding materials adopted to construct manmade tissues and organs. Commonly, therapeutic biomaterials can be classified into two main categories: living or once-living material of animal or human origin; and (II) other materials, including materials from vegetal sources and synthetic materials and their composites that are biocompatible and can be applied for tissue regeneration. For over two decades, progress in polymer science and tissue engineering has paved the way for the generation of sophisticated and ingenious biomaterials to optimize existing clinical treatments and to develop more safe and effective cures for a higher quality of human life.

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