Regenerative Nanomedicine

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Nanomedicine is the application of nanotechnology to medicine and healthcare. The field takes advantage of the physical, chemical and biological properties of materials at the nanometer scale to be used for diagnosis, treatment and follow-up of diseases. Given the immense potential impact of nanomedicine on public wellbeing and on economic growth, the field is of considerable strategic importance for medicine and healthcare.

Nanoscale materials should be designed according to the time-dependent requirements of target tissues to be regenerated in order to maximize the tissue-healing capacity of nano-devices. In spite of important progress in regenerative nanomedicine, there are still critical challenges for an advanced nanomedical approach to develop a clinical device. It may be necessary to mimic much of the complex, natural regenerative processes in order to repair diseased or damaged tissue.

Regeneration of dysfunctional or damaged tissues to restore their structure and function constitutes a main challenge in modern medicine. It can be addressed through the rapidly developing, multidisciplinary field of tissue engineering, which aims to form new functional tissue using optimal combinations of cells (autologous, allogeneic, xenogeneic, genetically engineered, or stem cells) and tailored biophysical and biochemical milieu capable of directing the organization, behaviour and functions of cells (e.g. adhesion, morphology, proliferation, differentiation). This approach requires the development of next-generation biomaterials that provide provisional bioactive 3-D scaffolds capable of guiding the spatially and temporally complex multicellular processes of tissue formation and regeneration [1-7].

Biomimetic matrices inspired from the intricate nanofibrillar architecture of natural extracellular matrix (ECM) components have already shown remarkable success in tissue engineering applications [5,8-10], allowing for instance, reconstruction of a dog urinary bladder [9], or regeneration after brain injury in a mouse stroke model [10]. However, it is established that durable tissue repair cannot be achieved with inert ECM-mimetic scaffolds. Ideally, scaffolds should also be equipped with bioactive molecules, including growth factors, angiogenic factors, differentiation factors and bone morphogenetic proteins to accelerate specific ECM production and tissue integration, or drugs to prevent adverse biological response such as sepsis or cancer recurrence [11]. To this end, strong benefits are expected from the combination of recent advances in (i) the design of nanoengineered ECM analogues [12-15], and (ii) strategies to enrich the surface of biomaterials with bioactive compounds [16-26].

Extracellular microenvironments play a critical role in the regulation of a range of cell behavior, including cell adhesion, proliferation, migration and differentiation [27,28]. In order to develop novel functional implants it is essential to construct suitable interfacial microenvironments—which both direct cell fates and improve interactions between cells and implant materials—on the surfaces of materials. With the advancement and convergence of materials science and biology, it is possible to construct biomimetic extracellular microenvironments on the surfaces of implants by combining functional drug-delivery systems with biomaterials [29,30]. Various strategies have been employed to construct extracellular microenvironments, such as functional proteins, fibrin hydrogels containing growth factor and anti-inflammatory drug-eluting multilayers[16-33]. We have also developed gene-stimulating microenvironments on titanium and poly(d,l-lactic acid) substrates via a layer-by-layer (LbL) assembly technique which were able to regulate cell functions, including the differentiation of mesenchymal stem cells (MSCs) [34,35].

The tissue-engineering approach is a promising strategy added in the field of bone regenerative medicine, which aims to generate new, cell-driven, functional tissues, rather than just to
implant non-living scaffolds. Three-dimensional porous scaffolds with specific architectures at the nano, micro and macro scale for optimum surface porosity and chemistry, which enhance cellular attachment, migration, proliferation and differentiation, are undergoing a continuous evaluation process.

References


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